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Ecosystem Restoration Program Plan Vol. 1. Programmatic EIS/EIR Technical Appendix

CalFed Bay-Delta Program

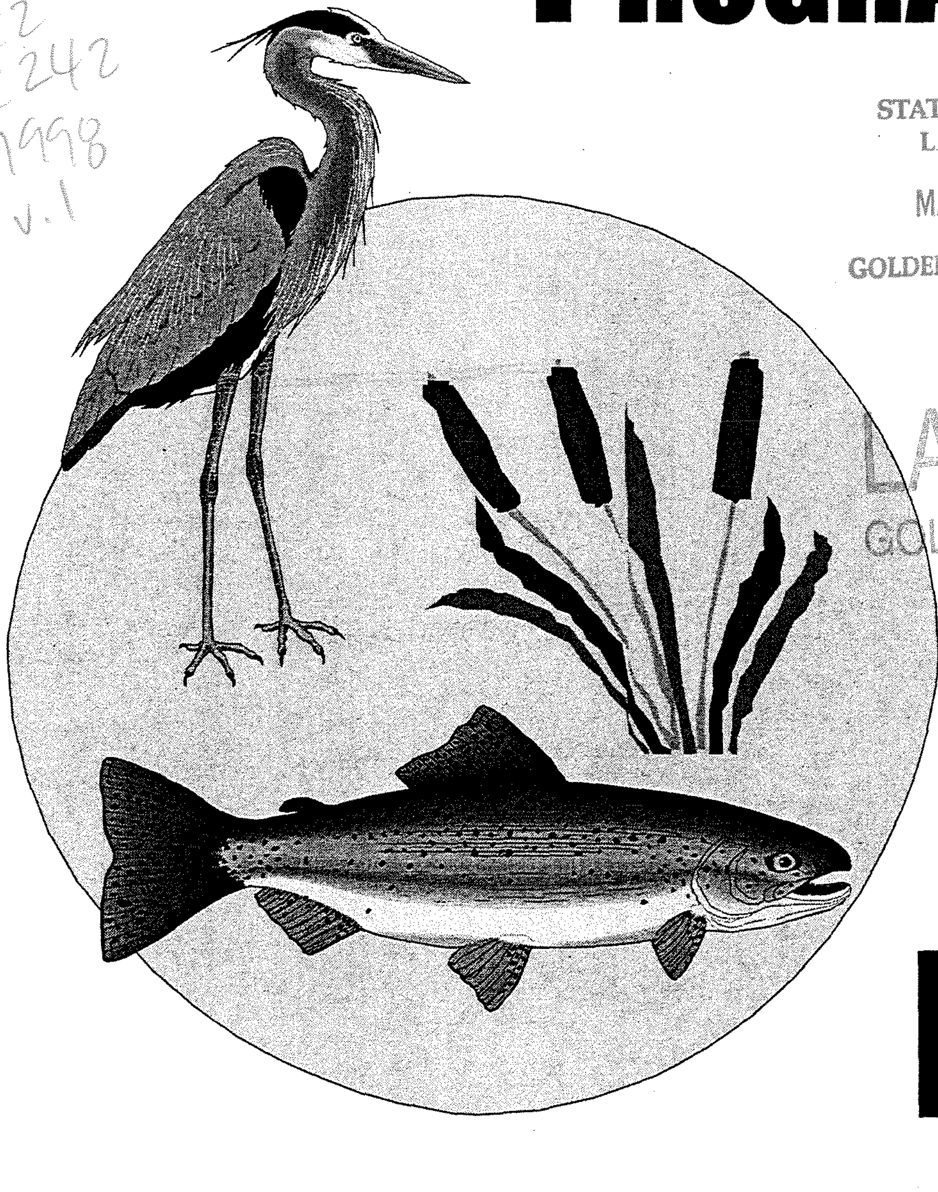
CALFED
BAY-DELTA
PROGRAM

Ecosystem Restoration Program Plan

Volume I

Programmatic EIS/EIR
Technical Appendix
March 1998

ECOSYSTEM RESTORATION PROGRAM PLAN



VOLUME I

VISIONS FOR ECOSYSTEM ELEMENTS

CALFED
BAY-DELTA
PROGRAM

Draft
March 1998

CALFED BAY-DELTA PROGRAM
ECOSYSTEM RESTORATION PROGRAM PLAN
VOLUME I: VISIONS FOR ECOSYSTEM ELEMENTS

TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

SECTION **PAGE**

TABLE OF CONTENTS (CONTINUED)

SECTION **PAGE**

TABLES

CALFED BAY-DELTA PROGRAM
ECOSYSTEM RESTORATION PROGRAM PLAN

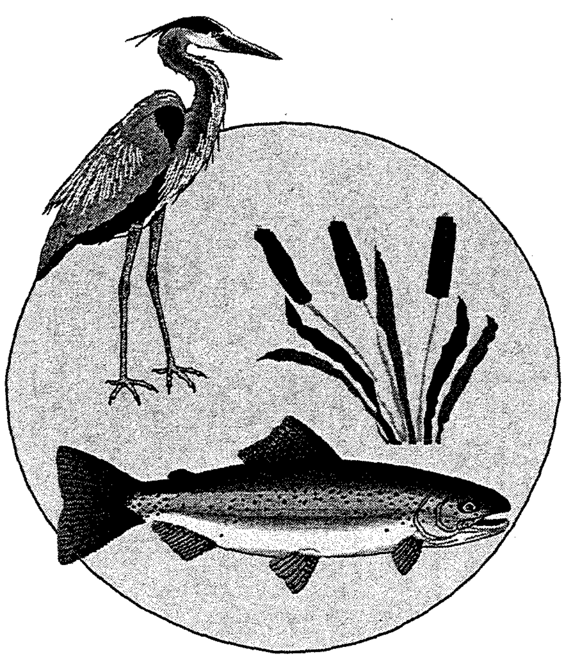
OVERVIEW

The mission of the CALFED Bay-Delta Program is to develop a long-term comprehensive plan that will restore ecosystem health and improve water management for beneficial uses of the Bay-Delta system. The Program addresses problems in four resource areas: ecosystem quality, water quality, levee system integrity, and water supply reliability. Programs to address problems in the four resource areas will be designed and integrated to fulfill the CALFED mission.

The goal for ecosystem quality is to improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species. The CALFED Ecosystem Restoration Program Plan (ERPP) addresses this goal. The foundation of the ERPP is restoration of ecological processes that are associated with streamflow, stream channels, watersheds, and floodplains. These processes create and maintain habitats essential to the life history of species dependent on the Delta. In addition, the Program aims to reduce the effects of stressors that inhibit ecological processes, habitats, and species.

The ecological hub of the Central Valley is the Sacramento-San Joaquin Delta and Bay. The ERPP signals a fundamental shift in the way ecological resources of the Central Valley are managed. For many decades, government entities, non-profit organizations, and the private sector have engaged in managing, protecting, regulating, and in some cases breeding fish and wildlife species of the Bay and Delta - yet many populations have not recovered sufficiently and remain in decline. In spite of constant human intervention to repopulate fish and wildlife that have commercial, recreational, and biological importance to society (e.g., hatchery programs and expensive re-engineered water diversions), populations have not been sustained at stable, healthy levels that support historic utilization of those resources.

Historic efforts at individual species regulation and management will be replaced by an integrated systems approach that aims to reverse the fundamental causes of decline in fish and wildlife populations. A systems approach will recognize the natural forces that created historic habitats and use these forces to help regenerate habitats. The Bay-Delta ecosystem is not simply a list of species. Rather, it is a complex living system sustained by innumerable interactions that are physical, climatic, chemical, and biological in nature, both within and outside of the geographic boundaries of the Delta. The central theme of the



ERPP is the recognition that truly durable and resilient populations of all fish and wildlife inhabiting the Bay and Delta require, above all else, the rehabilitation of ecological processes throughout the Central Valley river and estuary systems and watersheds.

The ERPP is fundamentally different from many past efforts in another way as well. It is not designed as mitigation for projects to improve water supply reliability or to bolster the integrity of Delta levees; improving ecological processes and increasing the amount and quality of habitat are co-equal with other program goals related to water supply reliability, water quality, and levee system integrity. Solving serious and long-standing problems in each of these resource areas will require an ambitious, integrated, long-term program.

The ERPP, like all components of Bay-Delta solution alternatives, is being developed and evaluated at a programmatic level. The complex and comprehensive nature of a Bay-Delta solution means that it will necessarily be composed of many different programs, projects, and actions that will be implemented over time. During the current phase of the Program, solution alternatives will be evaluated as sets of programs and projects so that broad benefits and impacts can be identified. In the next phase of the Program, more focused analysis, environmental documentation, and implementation of specific programs and actions will occur.

The CALFED goal for ecosystem quality will be achieved by developing implementation objectives and targets and programmatic actions that can be implemented to restore ecological processes. The restoration of these processes is intended to restore and maintain habitats, and to provide for the needs of the species dependent on a healthy Bay-Delta system. For example, restoring stream channels contributes to sediments, nutrients, and a variety of habitats. The strategy recognizes that not all processes can or should be completely restored and that intervention, manipulation, and management will be required. For example, streambed gravel may have to be introduced, habitats may have to be constructed, and vegetation planted. Still, an important part of the approach is to recommend measures that in the long-term will limit the need for continued human intervention.

Implementation of the ERPP is further guided by the recognition that all landscape units and physical and biological components of the ecosystem are interdependent and dynamic. Interdependence means that actions and stressors in one part of the system can and do affect populations and conditions that may be separated by hundreds of miles (e.g., in watersheds and spawning tributaries), or affect the food web in ways that may not be felt for several years.

Dynamic refers to the exposure of natural systems to constant cycles of change in response to both human and natural factors. Most habitats undergo expansions and contractions, or shifts in space and time. The dynamic nature of healthy habitats is the cause of much biological diversity, and complex habitats tend to make species populations more resilient to change. If the mosaic of habitats distributed across a broad landscape is complex, and if large areas of habitat are connected by smaller patches and corridors such as those associated with riparian systems, then healthy areas of the ecosystem can be relied upon to sustain species during temporary setbacks in other areas.

GEOGRAPHIC SCOPE

The geographic scope of the ERPP is defined by the interdependence and linkage of watersheds, streams, rivers and the Bay-Delta and the complex life histories of the dependent fish, wildlife and plant communities. The restoration of ecological processes requires implementation of actions throughout much of the Central Valley, its upper watersheds, the Bay-Delta, and near-shore ocean. The primary geographic focus is the Bay-Delta, the Sacramento River, the San Joaquin River, and their tributary watersheds directly connected to the Bay-Delta system below major dams and reservoirs. Secondarily, the ERPP addresses, at a programmatic level, the near-shore ocean and the upper watersheds above the major dams.

The primary geographic focus area for the ERPP can be divided into 14 zones, each characterized by a predominant physical habitat type and species assemblage (Figure 1). These 14 ecological zones constitute the geographic areas in which the majority of restoration actions will occur. The upper watersheds surrounding the primary focus area are important and addressed through general actions that focus on watershed processes.

IMPLEMENTATION STRATEGY

A large and diverse ecosystem like the Bay-Delta is extremely complex. There are many processes and relationships at work in the ecosystem that are not fully understood. Thus, there are many difficulties and uncertainties associated with a program to improve ecosystem health. In some cases, problems are well understood and the steps to improvement are clear. In other cases, there is some understanding of the reasons for decline but this understanding is not sufficient to warrant full-scale implementation of remedial measures. In still other cases, additional research is needed before solutions can be identified with certainty.

The difficulties and uncertainties of ecosystem restoration call for an implementation strategy that is flexible and can accommodate and respond to new information. The foundation of the ERPP implementation strategy is **adaptive management**. Adaptive management is a process of testing alternative ways of meeting objectives, and adapting future management actions according to what is learned. Adaptive management relies upon the identification of indicators of ecosystem health, comprehensive monitoring of indicators to measure improvement over time, focused research, and phasing of actions.

Indicators are features or attributes of the ecosystem that are expected to change over time in response to implementation of the ERPP. Indicators are selected to provide measurable evaluations of important ecological processes, habitats, and species whose status individually and cumulatively provide an assessment of ecological health. Indicators of ecosystem health are the gauges we will used to measure progress toward the goal. Some indicators are very broad in scale while others are very specific. For example, a very broad or landscape level indicator of ecosystem health might be a comparison of the total area of riparian forest to historic coverage or an evaluation of the average distance between patches of such forest with closer patches indicating better health than more distant patches. A more specific indicator might be the concentration of toxic substances in the flesh of adult striped bass.

Comprehensive monitoring is the process of measuring the abundance, distribution, change or status of indicators. For example, contaminant concentrations in fish tissues can be measured at various locations and times in the system to determine if contaminant levels are changing. This will allow progress to be measured, allow actions to be modified if necessary, and provide assurances that the restoration objectives are being achieved.

Focused research will help answer questions about the system and its components and increase the certainty surrounding the relationships of ecological processes, habitats, and species. For example, the relationships among streamflow, storm events, flow-related shaping of river channels to modify habitat, and the physical and chemical signals that flow provides for aquatic species all need to be better understood for effective management of the system.

Phasing is the logical sequence of implementing restoration actions to achieve CALFED goals as effectively as possible. Phasing will consider all targets and programmatic actions and will be used to prioritize actions. For example, actions directed at recovering endangered species and which are consistent with the long-term restoration program and contribute to ecological resilience have a high priority. Early phases of the program will include restoration of ecological processes and habitats that are most important for endangered species recovery, reduction of stressors that affect threatened and endangered species, and other actions that may reduce conflicts between beneficial uses in the system. As restoration progresses and threats to endangered species are reduced or eliminated, restoration efforts can expand and focus on the broader issue of restoring ecological health.

The ERPP will be refined and implemented according to the steps listed below.

1. **Refine** the ERPP based on broad public participation, and using the best scientific knowledge currently available in the short term.

2. **Create an Ecosystem Science Program** to provide ongoing scientific evaluation of the ERPP. The Science Program will be a collaborative effort among local and national, independent stakeholder and agency scientists and technical experts convened to address outstanding scientific issues and review the ERPP.

3. **Prepare conceptual models** to describe the Bay-Delta ecosystem and the proposed actions of the ERPP. Conceptual models are graphic and quantitative representations of ecosystem processes, habitats, species, and stressor interrelationships. Conceptual models will be used to test ERPP hypotheses.

4. **Develop testable hypotheses** for proposed ERPP actions. The hypotheses underlying the ERPP will be tested through experiments using the conceptual models and on-the-ground research. The results from these experiments will feed back into the adaptive management process and will support proposed actions, suggest revisions to actions, and identify needs for further research.

5. **Conduct immediate focused research** to improve understanding of the ecosystem and the causes of identified problems identified in the conceptual models and testable hypotheses. Use results from short-term studies to adjust the way that objectives are achieved, making refinements to the final ERPP targets, actions, and implementation schedule.

6. **Develop and begin a phased implementation** program that entails:

   - short-term implementation of ecosystem restoration demonstration projects (e.g., through Category III and related programs), including stressor reduction measures, to help threatened populations begin recovering and to test the viability and effectiveness of targets and actions,

   - coordinated monitoring, evaluation, and reporting of the results of recovery efforts, and the status of ecological indicators in the Bay-Delta and other zones, and

   - adaptive management of each successive phase of ERPP implementation, including pragmatic adjustments to ecosystem targets, funding priorities, and restoration techniques to ensure that public and private resources are well spent and complement other related efforts.

During refinement and implementation of the ERPP, public accountability and program effectiveness will be assured through continuing public involvement as well as environmental impact analysis and documentation.

TERMS USED IN THE ERPP

The following terms are used in the ERPP:

- **ECOSYSTEM ELEMENT:** An ecosystem element is a basic component or function which, when combined with other ecosystem elements, make up an ecosystem. An ecosystem element can be categorized as a process, habitat, species, species community or stressor.

- **ECOLOGICAL PROCESS:** Ecological processes act directly, indirectly, or in combination, to shape and form the ecosystem. These include streamflow, watershed, stream channel, and floodplain processes. Watershed processes are closely linked to streamflow and include fire and erosion. Stream channel processes include stream meander, gravel recruitment and transport, water temperature, and hydraulic conditions. Floodplain processes include overbank flooding and sediment retention and deposition.

- **HABITATS:** Habitats are areas that provide specific conditions necessary to support plant, fish, and wildlife communities. Some important habitats include gravel bars and riffles for salmon spawning beds, winter seasonal floodplains that support juvenile fish and waterbirds, and shallow near-shore aquatic habitat shaded by overhanging tule marsh and riparian forest.

- **SPECIES AND SPECIES GROUPS:** Certain species or groups of species are given particular attention in the ERPP. This focus is based on three criteria that might be met by a species: 1) it is threatened, endangered, or a species of special concern (e.g., delta smelt); 2) it is economically important, supporting a sport or commercial fishery (e.g., striped bass); or 3) it is an important prey species (e.g., Pacific herring).

- **STRESSORS:** Stressors are natural and unnatural events or activities that adversely affect ecosystem processes, habitats, and species. Environmental stressors include water diversions, water contaminants, levee confinement, stream channelization and bank armoring, mining and dredging in streams and estuaries, excessive harvest of fish and wildlife, introduced predator and competitor species, and invasive plants in aquatic and riparian zones. Some major stressors affecting the ecosystem are permanent features on the landscape, such as large dams and reservoirs that block transport of the natural supply of woody debris and sediment in rivers or alter unimpaired flows.

- **VISION:** A vision is what the ERPP will accomplish with the stated objectives, targets, and programmatic actions for an ecological process, habitat, species or species group, stressor, or geographical unit. The vision statements included in the ERPP provide technical background to increase understanding of the ecosystem and its elements. Two types of vision statements are included in the ERPP: visions for ecosystem elements and visions for ecological zone. A resource vision addresses an individual ecological processes, habitat, species or species group, or stressor, while an ecological zone vision addresses the integration of ecological processes, habitats, species, and stressors within a clearly delineated geographical area. Cumulatively, the visions also provide detailed descriptions of the ecosystem and its elements as they will look and function after restoration is accomplished.

- **IMPLEMENTATION OBJECTIVE:** An implementation objective is the most specific and detailed description of what the ERPP strives to maintain or achieve for an ecosystem element. Implementation objectives are not intended to change over the life of the program. For example, the implementation objective for tidal perennial aquatic habitat is to increase the area of shallow-water and intertidal mudflat habitat to improve conditions that support increased primary and secondary productivity; provide rearing and foraging habitat, and escape cover for fish; and provide foraging and resting habitat, and escape cover for water birds.

- **TARGET:** A target is a qualitative or quantitative statement of an implementation objective. Targets are something to strive for but may change over the life of the program with new information and progress, or may vary according to the configuration of storage and conveyance in all alternatives. Targets may include a range of values or a narrative description of the proposed future value of an ecosystem element. Targets are to be set based upon realistic expectations, must be balanced against other resource needs and must be reasonable, affordable, cost effective, and practicably achievable.

  The intent of the ERPP is to achieve ecosystem health; targets are flexible tools to guide the effort. The level of implementation for each target will be determined or adjusted through adaptive management. Targets are categorized according to the three levels of certainty described above: (1) targets that have sufficient certainty of success to justify full implementation in accordance with program priorities and phasing; (2) targets which will be implemented in stages with the appropriate monitoring and evaluation to judge benefits and successes; and (3) targets for which additional research, demonstration and evaluations are needed to determine feasibility or ecosystem response.

  An example of a target for tidal perennial aquatic habitat is to restore 1,500 acres of shallow-water habitat in the Suisun Bay and Marsh Ecological Unit, and restore 1,000 acres of shallow-water habitat in the San Pablo Bay Unit.

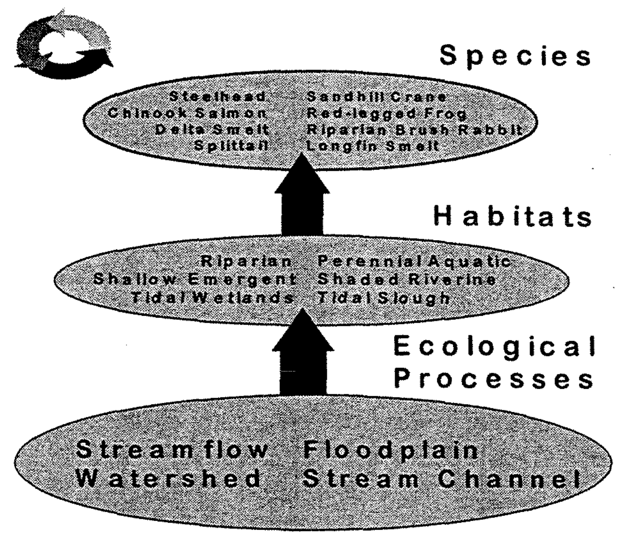


Figure 2. Relationship of ecological, processes, habitats, and species in the Ecosystem Restoration Program Plan.

- **PROGRAMMATIC ACTION:** A programmatic action represents a physical, operational, legal, institutional change or alternative means to achieve a target. The number of actions and their level of implementation is subject to adjustment by adaptive management. For example, the number of diversions screened may be adjusted up or down depending on the overall response of fish populations to screening and other restoration actions.

  An example of a programmatic action is to develop a cooperative program to acquire and restore 1,500 acres of shallow-water habitat in the Suisun Bay and Marsh Ecological Zone.

The relationship of ecological processes, habitats, and species is presented in Figure 2.

ORGANIZATION OF THE PLAN

The ERPP is comprised of three volumes:

- **Volume I: Visions for Ecosystem Elements,**

- **Volume II: Ecological Zone Visions,**
- **Volume III: Vision for Adaptive Management**

VOLUME I: VISIONS FOR ECOSYSTEM ELEMENTS presents the visions for ecological processes and functions, fish and wildlife habitats, species, and stressors that impair the health of the processes, habitats, and species. The visions presented in Volume I are the foundation of the ERPP and displays how the many ecosystem elements relate to one another and establishes a basis for actions which are presented in Volume II.

VOLUME II: ECOLOGICAL ZONE VISIONS presents the visions for the 14 ecological zones and their respective ecological units. Each individual ecological zone vision contains a brief description of the ecological zone and units, important ecological functions associated with the zone, important habitats, species which use the habitats, and stressors which impair the functioning or utilization of the processes and habitats. Volume II also contains implementation objectives, targets, and programmatic actions which describe the ERPP approach to improving the ecological health of the zone and its contribution to the health of the Delta. Rationale are also contained in Volume II which clarify, justify, or support the targets and programmatic actions.

VOLUME III: VISION FOR ADAPTIVE MANAGEMENT provides the ERPP approach to adaptive management and contains the proposed plans for indicators of ecological health, a monitoring program to acquire and evaluate the data needed regarding indicators, a program of focused research to acquire additional data needed to evaluate program alternatives and options, and the approach to phasing the implementation of the ERPP over time.

INTRODUCTION TO VOLUME I

Volume I (Visions for Ecosystem Elements) contains information related to important ecological processes and functions, habitats,species, and stressors which impair or otherwise adversely effect the other ecosystem elements. Individually and cumulatively, the visions for the ecosystem elements establish the foundation and scientific basis of the ERPP.

Volume I is divided into four sections: (1) ecological process visions, (2) habitat visions, (3) species visions, and (4) visions for reducing or eliminating stressors. Each section follows the same format and begin with introductory information regarding the ecosystem elements. Three introductory tables summarize the implementation objectives, basis for selections as an ecosystem element, and the distribution of ecosystem elements by ecological zone.

Individual visions begin with an introduction followed by a description of the relevant process, habitats, species, or stressor. These are followed by the ERPP vision for the element, how restoration of the process, habitat, or species, or reduction or elimination of the stressor integrates with other ongoing restoration or management programs. The relationship or linkage of the ecosystem elements to other elements is then discussed followed by a presentation of the implementation objective, targets, and summary of programmatic actions.

The identity and summary visions for each ecosystem element follow in Table 1.

TABLE 1. SUMMARY OF VISIONS FOR ECOSYSTEM ELEMENTS

Ecosystem Element	Vision Summary
ECOSYSTEM PROCESSES	
CENTRAL VALLEY STREAMFLOWS	The vision for Central Valley streamflows is to protect and enhance the ecological functions that are achieved through the multitude of physical and biological processes that operate within the stream channel and associated riparian and floodplain areas in order to contribute to the recovery of species and the overall health of the Bay-Delta.
NATURAL SEDIMENT SUPPLY	The vision for natural sediment supply is to provide a sustained supply of alluvial sediments that are transported by rivers and streams and distributed to riverine bed deposits, floodplains, channel bars, riffles, shallow shoals, and mudflats, throughout the Sacramento-San Joaquin Valley, Delta, and Bay regions. This would contribute to habitat structure, function, and foodweb production throughout the ecosystem.
STREAM MEANDER	The vision for stream meander is to conserve and reestablish areas of active stream meander, where feasible, by implementing stream conservation programs, setting levees back, and reestablishing natural sediment supply to restore riverine and floodplain habitats for fish and wildlife.
NATURAL FLOODPLAINS AND FLOOD PROCESSES	The vision for natural floodplains and flood processes is to maintain or restore the processes that sustain them by conserving existing intact floodplains and modifying or removing barriers to overbank flooding to reestablish aquatic, wetland, and riparian floodplain habitats.
CENTRAL VALLEY STREAM TEMPERATURES	The vision for Central Valley stream temperatures is to restore natural seasonal patterns of water temperature in streams, rivers, and the Delta by protecting and improving ecological processes that regulate water temperature and reducing stressors that change water temperature.
BAY-DELTA HYDRAULICS	The vision for hydraulic processes in the Sacramento-San Joaquin Delta is to restore channel hydraulics to conditions more like those that occurred during the mid-1960s. Historical hydraulic conditions provided migratory cues for aquatic species; transport flows for eggs, larvae, and juvenile fish; and transport of sediments and nutrients.
BAY-DELTA AQUATIC FOODWEB	The vision for the Bay-Delta aquatic foodweb is to restore primary and secondary production to levels comparable to those during the 1960s and early 1970s. Restoring the Bay-Delta foodweb would require enhancing productivity and reducing loss of productivity as a result of water exports from the system, particularly in drier years.
UPPER WATERSHED PROCESSES: FIRE AND EROSION	The vision for upper watershed health and function is to reduce the level of stressors including wildfire, erosion, excessive timber harvest and livestock grazing, and other damaging land use management practices that constrain watershed health and the ability to contribute to the health of the Bay-Delta ecosystem.

Ecosystem Element	Vision Summary
HABITATS	
TIDAL PERENNIAL AQUATIC HABITAT	The vision for tidal perennial aquatic habitats is to increase the area and improve the quality of existing connecting waters associated with tidal emergent wetlands and their supporting ecosystem processes. Achieving this vision will assist in the recovery of special-status fish populations and provide high-quality aquatic habitat for other fish and wildlife dependent on the Bay-Delta. Restoring tidal perennial aquatic habitat would also result in higher water quality and increase the amount of shallow-water and mudflat habitats; foraging and resting habitats and escape cover for water birds; and rearing and foraging habitats, and escape cover for fish.
NONTIDAL PERENNIAL AQUATIC HABITAT	The vision for nontidal perennial aquatic habitat is to increase the area and improve the quality of existing open-water areas to provide high-quality habitat for waterfowl and other water birds. This vision can be achieved as a component of saline and freshwater emergent wetland restorations.
DELTA SLOUGHS	The vision for Delta sloughs is to increase the area and improve the quality of interconnected dead-end and open-ended Delta sloughs. Achieving this vision will assist in the recovery of special-status fish and wildlife populations, provide shallow-water habitats for fish spawning and rearing, and provide aquatic, wetland, and riparian habitat for wildlife. Existing sloughs would be protected and enhanced and the area of tidal slough habitat would be increased.
MIDCHANNEL ISLANDS AND SHOALS	The vision for midchannel islands and shoals is to increase the area and protect the quality of existing habitat for fish and wildlife dependent on the Bay-Delta.
SALINE EMERGENT WETLAND	The vision for saline emergent wetlands is to increase the area and protect the quality of existing saline emergent wetlands from degradation or loss. Wetland habitat will be increased to assist in the recovery of special-status plant, fish, and wildlife populations. Restoration will provide high-quality habitat for other fish and wildlife dependent on the Bay-Delta.
FRESH EMERGENT WETLAND	The vision for fresh emergent wetlands is to increase the area and improve the quality of existing fresh emergent wetlands from degradation or loss and increase wetland habitat. Achieving this vision will assist in the recovery of special-status plant, fish, and wildlife populations, and provide high-quality habitat for other fish and wildlife dependent on the Bay-Delta.
SEASONAL WETLANDS	The vision for seasonal wetlands is to increase the area and improve the quality of seasonal wetlands by restoring ecosystem processes that sustain them and reduce the effect of stressors that can degrade the quality of seasonal wetlands in order to assist in the recovery of special-status plant and animal populations and provide high-quality habitat for waterfowl, water birds, and other wildlife dependent on the Bay-Delta.

Ecosystem Element	Vision Summary
RIPARIAN AND RIVERINE AQUATIC HABITATS	The vision for riparian and riverine aquatic habitats is to increase their area and protect and improve their quality. Achieving this vision will assist in the recovery of special-status fish and wildlife populations and provide high-quality habitat for other fish and wildlife dependent on the Bay-Delta. The vision includes restoring native riparian communities ranging from valley oak woodland associated with higher, less frequently inundated floodplain elevations to willow scrub associated with low, frequently inundated floodplain elevation sites such as streambanks, point bars, and inchannel bars.
INLAND DUNE SCRUB HABITAT	The vision for inland dune scrub habitat is to protect and enhance existing areas and restore former habitat areas. Achieving this vision will provide high-quality habitat for associated special-status plant and animal populations.
PERENNIAL GRASSLAND	The vision for perennial grassland is to protect and improve existing perennial grasslands and increase grassland area. This vision is a component of restoring wetland and riparian habitats. Achieving this vision will provide high-quality habitat for special-status plant and wildlife populations and other wildlife dependent on the Bay-Delta.
AGRICULTURAL LANDS	The vision for agricultural lands is to improve associated wildlife habitat values to support special-status wildlife populations and other wildlife dependent on the Bay-Delta. Protecting and enhancing agricultural lands for wildlife would focus on encouraging production of crop types that provide high wildlife habitat value, agricultural land and water management practices that increase wildlife habitat value, and discouraging development of ecologically important agricultural lands for urban or industrial uses in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones.
SPECIES AND SPECIES GROUPS	
DELTA SMELT	The vision for delta smelt is to ensure the recovery of this State- and federally listed threatened species in order to contribute to the overall species richness and diversity of the Bay-Delta. Achieving this vision will reduce the conflict between protection for this species and other beneficial water uses in the Bay-Delta. Increases in the population and distribution of delta smelt can be realized through habitat restoration accompanied by reductions in stressors.
LONGFIN SMELT	The vision for longfin smelt is to improve the population of this species of special concern in the Bay-Delta estuary so that it resumes its historical levels of abundance and its role as an important prey species in the Bay-Delta aquatic foodweb.
SPLITTAIL	Assist in the recovery of the of splittail, a species proposed for listing under the federal Endangered Species Act (ESA) and a candidate for listing under the California ESA in order to contribute to the overall species richness and diversity and to reduce conflict between protection for this species and other beneficial uses of water in the Bay-Delta.

Ecosystem Element	Vision Summary
WHITE AND GREEN STURGEON	The vision for white and green sturgeon is to restore population distribution and abundance to historical levels. Restoration of these species would support a sport fishery for white sturgeon, ensure recovery of the green sturgeon population, and contribute to overall species richness and diversity and reduce conflict between the need for protection for these species and other beneficial uses of water in the Bay-Delta.
CHINOOK SALMON	The vision for Central Valley chinook salmon is to achieve naturally spawning population levels that support and maintain ocean commercial and ocean and inland recreational fisheries, and that fully use existing and restored habitats. This vision will contribute to the overall species diversity and richness of the Bay-Delta system and reduce conflict between protection for this species and other beneficial uses of water and land in the Central Valley.
STEELHEAD TROUT	The vision for Central Valley steelhead trout is to achieve naturally spawning populations of sufficient size to support inland recreational fishing and that fully use existing and restored habitat areas. Achieving this vision will primarily require restoring degraded spawning and rearing habitats, enhancing fish passage to historic habitat, and supporting angling regulations consistent with steelhead trout population recovery. This vision is consistent with restoring populations of steelhead to levels that eliminate the need for any future protection under the State and federal Endangered Species Acts (ESAs).
STRIPED BASS	The vision for striped bass is to restore populations to their 1960s level of abundance to support a sport fishery in the Bay, Delta, and tributary rivers, and to reduce the conflict between protection of striped bass and other beneficial uses of water in the Bay-Delta.
AMERICAN SHAD	The vision for American shad is to maintain a naturally spawning population that supports a sport fishery similar to the fishery that existed in the 1960s and 1970s. Achieving this vision will reduce the conflict between protection of this species and other beneficial uses of water in the Bay-Delta.
RESIDENT FISH SPECIES	The vision for resident fish species is to maintain and restore the distribution and abundance of native species, such as Sacramento blackfish, hardhead, tule perch, and Sacramento perch; and non-native species, such as white catfish, largemouth bass, and threadfin shad, to support a sport fishery and healthy nongame fish populations. Although the Sacramento perch no longer occurs in the Delta, it is included with resident native species because actions to maintain and restore other resident species populations would benefit Sacramento perch in the event they are reintroduced to the Delta.
MARINE/ESTUARINE FISHES AND LARGE INVERTEBRATES	The vision for marine/estuarine fishes is to restore populations to levels that existed in the early 1980s through restoration of habitat and aquatic foodweb, and improvements in winter-spring Delta outflow.
BAY-DELTA AQUATIC FOODWEB ORGANISMS	The vision for the Bay-Delta aquatic foodweb organisms is to restore the Bay-Delta estuary's once-productive food base of aquatic algae, organic matter, microbes, and zooplankton communities.

Ecosystem Element	Vision Summary
WESTERN SPADEFOOT AND CALIFORNIA TIGER SALAMANDER	The vision for the western spadefoot and the California tiger salamander is to assist in the recovery of these species in the Bay-Delta. Achieving this vision will contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of land and water in the Bay-Delta.
CALIFORNIA RED-LEGGED FROG	The vision for the California red-legged frog is to assist in the recovery of this federally listed threatened species. Achieving this vision will contribute to the overall species richness and diversity and to reduce conflict between protection for this species and other beneficial uses of land and water in the Bay-Delta.
GIANT GARTER SNAKE AND WESTERN POND TURTLE	The vision for the giant garter snake and western pond turtle is to assist in their recovery in order to contribute to the overall species richness and diversity. Achieving this vision will reduce the conflict between protection for this species and other beneficial uses of land and water in the Bay-Delta.
SWAINSON'S HAWK	The vision for the Swainson's hawk is to assist in the recovery of this State-listed threatened species to contribute to the overall species richness and diversity. Achieving this vision will reduce conflict between protection for this species and other beneficial uses of land and water in the Bay-Delta.
CALIFORNIA CLAPPER RAIL	The vision for the California clapper rail is to assist in the recovery of this State- and federally listed endangered species to contribute to overall species richness and diversity. Achieving this vision will reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
CALIFORNIA BLACK RAIL	The vision for the California black rail is to assist in the recovery of this State-listed threatened species to contribute to overall species richness and diversity. Achieving this vision will reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
GREATER SANDHILL CRANE	The vision for the greater sandhill crane is to assist in the recovery of this State-listed threatened species in the Bay-Delta. Recovery of the greater sandhill cane would contribute to overall species richness and diversity. Achieving this vision will reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
WESTERN YELLOW-BILLED CUCKOO	The vision for the western yellow-billed cuckoo is to assist in the recovery of this State-listed endangered species. Recovery of this species would contribute to overall species richness and diversity. Achieving this vision will reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
BANK SWALLOW	The vision for the bank swallow is to assist in the recovery of this State-listed threatened species. Recovery of the bank swallow would contribute to overall species richness and diversity. Achieving this vision will reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

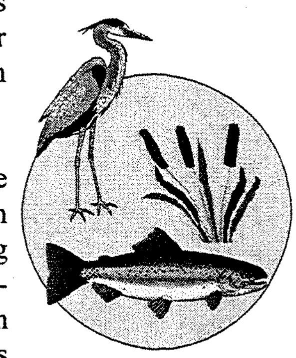
Ecosystem Element	Vision Summary
SUISUN SONG SPARROW	The vision for the Suisun song sparrow is increase the habitat of this species of concern in Suisun Marsh and the western Delta.
SALT MARSH HARVEST MOUSE	The vision for the salt marsh harvest mouse is to assist in the recovery of this State- and federally listed endangered species through restoring salt marsh in San Pablo and Suisun Bays and adjacent marshes. Existing occupied and unoccupied suitable habitat areas will be protected. Saline emergent wetlands will be restored. Stressors to the population and habitat will be reduced. new populations will be introduced into unoccupied habitat areas.
RIPARIAN BRUSH RABBIT	The vision for the riparian brush rabbit is to assist in the recovery of this State-listed endangered species in the Bay-Delta through improvements in riparian habitat and reintroduction to its former habitat.
SHOREBIRD AND WADING BIRD GUILD	The vision for the shorebird and wading bird guild is to maintain healthy populations of shorebirds and wading birds through habitat protection and restoration and reduction in stressors.
WATERFOWL	The vision for waterfowl is to maintain healthy populations at levels that can support consumptive (e.g., hunting) and nonconsumptive (e.g., birdwatching) uses consistent with the goals and objectives of the Central Valley Habitat Joint Venture as part of the North American Waterfowl management Plan.
UPLAND GAME	The vision is to maintain healthy populations of upland game species at levels that can support both consumptive (e.g., hunting) and nonconsumptive (e.g., birdwatching) uses, through protection and improvement of habitats and reduction in stressors.
NEOTROPICAL MIGRATORY BIRD GUILD	The vision for the neotropical migratory bird guild is to maintain healthy populations of neotropical migratory birds through restoring habitats on which they depend.
SPECIAL-STATUS PLANT SPECIES	The vision for special-status plant species is to contribute to their continued existence by protecting and preserving important habitat sites within the Bay-Delta.
PLANT COMMUNITY GROUPS	The vision for plant community groups is to protect existing and rehabilitate degraded habitats that support the diverse assemblages of plants in the Bay-Delta.
LANGE'S METALMARK, DELTA GREEN GROUND BEETLE, AND VALLEY ELDERBERRY LONGHORN BEETLE	The vision for the Lange's metalmark, the delta green ground beetle, and valley elderberry longhorn beetle is to assist in maintaining the existing Lange's metalmark population and by maintaining its abundance, and to assist in the recovery of the delta green ground beetle and valley elderberry longhorn beetle by increasing their populations and abundance through habitat restoration.
STRESSORS	

Ecosystem Element	Vision Summary
WATER DIVERSIONS	The vision for water diversions is to reduce the adverse effects of water diversions, including entrainment of all life stages of aquatic species. Achieving this vision will assist in the recovery of State- and federally listed fish species, improve important sport fisheries, and improve the Bay-Delta aquatic foodweb.
DAMS, RESERVOIRS, WEIRS, AND OTHER STRUCTURES	The vision for dams, reservoirs, weirs, and other structures is to reduce their adverse effects by improving fish passage and enhancing downstream fish habitat. Reducing these adverse effects will assist in the recovery of State- and federally listed fish species and contribute to sustainable sport and commercial fisheries.
LEVEES, BRIDGES, AND BANK PROTECTION	The vision for levees, bridges, and bank protection is to reduce the adverse effects of these structures in order to improve riverine and floodplain habitat conditions to assist in the recovery of State- and federally listed fish species, and other fish and wildlife.
DREDGING AND SEDIMENT DISPOSAL	The vision for dredging and sediment disposal in the Bay-Delta is to maintain adequate channel depth for navigation, flood control, and water conveyance while reducing the adverse effects of dredging activities on the Bay-Delta ecosystem. Dredged material disposal would be environmentally sound and the use of nontoxic dredged material would be promoted as a resource for restoring tidal wetlands and other habitats, reversing Delta island subsidence, and improving dikes and levees.
GRAVEL MINING	The vision for gravel mining is to improve gravel transport and cleansing by reducing the adverse effects of instream gravel mining. Achieving this vision would help to maintain or restore flood, floodplain, and streamflow processes that govern gravel supply to improve fish spawning and floodplain habitats.
INVASIVE AQUATIC PLANTS	The vision for invasive aquatic plants is to reduce their adverse effects on native species and ecological processes, water quality and conveyance systems, and major rivers and their tributaries.
INVASIVE AQUATIC ORGANISMS	The vision for invasive aquatic organisms is to reduce their adverse effects on the foodweb and on native species resulting from competition for food and habitat and direct predation. This vision can be accomplished through enforcement of State laws regulating ballast water dumping and other measures designed to reduce the number of new, potentially harmful species introduced accidentally into the Bay-Delta estuary. Habitat changes or direct control measures may reduce their effects in specific cases.
INVASIVE RIPARIAN AND SALT MARSH PLANTS	The vision for invasive riparian and salt marsh plant species is to reduce their adverse effects on native species and ecological processes, water quality and water conveyance systems, and major rivers and their tributaries.
NON-NATIVE WILDLIFE	The vision for non-native wildlife species is to implement a program to reduce the numbers of harmful non-native wildlife species (i.e., those that threaten the diversity or abundance of native species or the ecological stability of an area).

Ecosystem Element	Vision Summary
PREDATION AND COMPETITION	The vision for predation and competition is to reduce unnatural levels to restore fish populations by removing, redesigning, or reoperating inwater structures, diversion dams, and hatchery practices.
CONTAMINANTS	The vision regarding contaminants is to ensure that all waters of mainstem rivers and tributaries entering the Bay-Delta, and all waters of the Bay-Delta, are free of high concentrations of toxic substances. The vision includes preventing, controlling, or reducing damaging levels of high-priority contaminants by remediating mine wastes, minimizing boat discharges and dredging effects, managing flows, restoring habitat, managing watersheds, and supporting existing programs for controlling agricultural and urban point and nonpoint sources.
WILDFIRE	The vision for wildfire is to support programs that will reduce the acreage and frequency of catastrophic wildfires and the consequences of wildfires. Reducing the extent and effects of wildfires in tributary watersheds of the Bay-Delta would reduce the threats posed by catastrophic wildfire on fish and wildlife habitats through deforestation and resulting high levels of erosion and increased rates of surface runoff.
FISH AND WILDLIFE HARVEST	The vision for fish and wildlife harvest is to support strategies that maintain a sustainable commercial and recreational chinook salmon fishery in a manner consistent with the recovery; of individual stocks; steelhead trout harvest strategies that fully protect naturally spawning stocks while redirecting harvest to hatchery-produced stocks; the continued legal harvest of striped bass and reduction of illegal harvest; and the present white sturgeon harvest strategy, which protects the species from overexploitation while providing a sustainable trophy fishery.
ARTIFICIAL FISH PROPAGATION	The vision for the artificial propagation of fish is closely linked to the visions for harvest, chinook salmon, steelhead trout, and striped bass. Cumulatively, these visions present a robust integration of production, harvest, and restoration targets and actions that will contribute substantially to restoring and maintaining a healthy ecosystem and healthy populations of valuable sport and commercial fisheries.
DISTURBANCE	The vision for disturbance is to reduce the adverse effects of boating and other recreational activities, temporary habitat disturbances, and other human activities on wildlife and their habitats in the Bay-Delta.

INTRODUCTION

This section presents visions for ecological processes. Ecological processes act directly, indirectly, or in combination, to shape and form the ecosystem. These include streamflow, watershed, stream channel, and floodplain processes. Watershed processes are closely linked to streamflow and include fire and erosion. Stream channel processes include stream meander, gravel recruitment and transport, water temperature, and hydraulic conditions. Floodplain processes include overbank flooding and sediment retention and deposition. Physical and biological processes addressed are those that have a strong effect in shaping and influencing the Bay-Delta ecosystem. These processes can also be managed to improve the health of the Bay-Delta ecosystem and its resources. Table 2 identifies important ecological processes and the related ERPP implementation objectives. Implementation objectives are fixed and will not change through time. Table 3 presents the basis for their selection as an ecosystem element.



Visions describe the role and importance of each process in maintaining the health of the Bay-Delta, and a description of how the process currently operates in the ecosystem, stressors and changes to other processes that have altered how they operate in the ecosystem. The ERPP implementation objectives, targets, and programmatic actions are presented here and more fully described in Volume II: Ecological Zone Visions. Table 4 presents the ecological zone in which implementation objectives, targets, an programmatic actions have been proposed to accomplish each ecological process vision.

TABLE 2. ECOLOGICAL PROCESSES AND ERPP IMPLEMENTATION OBJECTIVES

Ecological Process	Implementation Objective
Central Valley Streamflows	restore basic hydraulic conditions to reactivate and maintain ecological processes that create and sustain habitat required for healthy fish, wildlife, and plant populations.
Natural Sediment Supply	provide sufficient quantities to riverine and estuarine systems to restore or reactivate stream channel meander and point bar formation, provide sediments to rebuild wetlands and shallow-water habitats, and provide for nutrient transport.
Stream Meander	maintain, improve, or restore natural stream meander processes to allow the natural recruitment of sediments, create habitats, and promote riparian succession.

Natural Floodplains and Flood Processes	modify channel and basin configurations to improve floodplain function along rivers and streams in the Sacramento-San Joaquin basin.
Central Valley Stream Temperatures	maintain, improve, and restore water temperature regimes to meet the life-history needs of aquatic organisms.
Bay-Delta Hydraulics	establish and maintain a hydraulic regime in the Bay-Delta to provide migratory cues, create and maintain habitat, and facilitate species distribution and transport.
Bay-Delta Aquatic Foodweb	maintain, improve, or restore the amount of basic nutrients available to estuarine and riverine systems to provide a sustainable level of foodweb productivity.
Upper Watershed Processes - Fire and Erosion	restore ecological processes in the upper watersheds to maintain and improve the quality and quantity of water flowing into the tributaries and rivers of the Sacramento-San Joaquin Delta and San Francisco Bay.

TABLE 3. BASIS FOR SELECTION OF ECOLOGICAL PROCESS ECOSYSTEM ELEMENTS

Ecological Process	Basis for Selection as an Ecosystem Element
Central Valley Streamflows	Streamflow refers to the total amount and seasonal distribution of water entering the ecosystem, including surface and groundwater, and includes episodic events such as floodflows and drought cycles. The total volume and distribution in time and location of water supports other important ecological processes and functions that sustain habitats and many species of the Bay-Delta, the Sacramento and San Joaquin Rivers, and their tributaries. Human activities have had a large influence on the natural hydrograph of the Bay-Delta and the Sacramento-San Joaquin basin. There are opportunities to restore or simulate, where appropriate, more natural streamflow patterns that sustain ecological functions and meets the life requirements of plants and animals.
Natural Sediment Supply	The natural sediment supply of Central Valley rivers and streams comprises mineral and organic fines, sands, gravel, cobble, and woody debris. Sediment, like water, is one of the natural building blocks of the ecosystem on which many other ecological processes, functions, habitats, and species depend. Gravel, for example, is important for maintaining spawning habitat of salmon and supports the many invertebrates on which young salmon prey. Finer sediments sustain riparian and wetland habitats. Human activities have had a large effect on natural sediment processes in the watershed. There are opportunities to restore natural sediment processes or to compensate for the loss of sediment supply from building levees, dams, and reservoirs to meet the life requirements of plants and animals.
Stream Meander	Stream meander corridors are areas in which natural bank erosion and floodplain and sediment bar accretion occur along stream courses. Natural stream meanders in alluvial systems function dynamically to transport and deposit sediments and provide transient habitats important to algae, aquatic invertebrates, and fish, as well as surfaces that are colonized by natural riparian vegetation that supports wildlife.
Natural Floodplains and Flood Processes	Floodwater and sediment detention and retention is the process whereby flows and sediment are retained within floodplains of the Sacramento-San Joaquin basin. Retention and detention of water and sediment within basin floodplains are a secondary process controlled primarily by flow patterns and channel geomorphology, and secondarily by soils and plant communities. Floodwater storage and retention reduce flood effects, soil erosion, peat oxidation, and nutrient loss. The process stores water and sediment either permanently or temporarily, reducing the peak loads of both downstream systems. Overbank flooding is a secondary process to water and sediment flow through the Sacramento-San Joaquin basin in combination with geomorphology. Flooding of lands provides important seasonal habitat for fish and wildlife and provides sediment and nutrients to both the flooded lands and aquatic habitats that receive the returning or abating floodwaters. The flooding also shapes the plant and animal communities in the riparian, wetland, and uplands habitat subject to inundation. Opportunities to restore or enhance this process are possible by changing landscape features, geomorphology, and seasonal distribution of flow volume through the system.

Ecological Process	Basis for Selection as an Ecosystem Element
Central Valley Stream Temperatures	Water temperature is determined by the natural heating and cooling process of water bodies and flows in the Sacramento-San Joaquin basin. Water temperature in the Sacramento-San Joaquin basin is controlled by water source (i.e., dam releases; runoff; and agricultural, municipal, and industrial discharges); surface and groundwater flow; geomorphology; tides; riparian shading; and, most often, air temperature. Water temperature is an important factor in habitat suitability for aquatic organisms. Unnaturally high water temperatures can become stressors to many aquatic organisms.
Bay-Delta Hydraulics	The natural hydraulic regime refers to the direction and velocity of flows in the Bay-Delta channels on a temporal, tidal, and seasonal basis for a given hydrologic condition. The direction and velocity of flows and their distribution in time and location support important ecological processes and functions in the Bay-Delta that sustain the foodweb, influence the spawning, rearing, and feeding of estuarine and anadromous fish, and support migration of adult and juvenile fish. Human activities have had a large influence on the natural hydraulic regime of the Bay-Delta. There are opportunities to restore or simulate, where and when appropriate, a more natural hydraulic regime that sustains ecological functions and meets the life requirements of fish and wildlife in or dependent on the Bay-Delta.
Bay-Delta Aquatic Foodweb	The Bay-Delta aquatic foodweb is driven by primary, secondary, and tertiary production. Primary production refers to the energy produced by algae and other plants through photosynthesis. Primary production of plants in the Sacramento-San Joaquin basin is the basic process that supports the biological system. Nearly all ecological processes have some effect on primary production in the basin. Human activities have altered production in many ways and opportunities to enhance this process exist by manipulating waterflow, nutrients, and geomorphology and alleviating environmental stressors such as salts, herbicides, and other toxins in watercourses. Secondary production refers to the production of organisms from feeding on plant materials. Secondary production in the Sacramento-San Joaquin basin occurs primarily through the breakdown of plant materials by microorganisms, such as bacteria, fungi, protozoans, and zooplankton, and through large-animal grazing. Tertiary production refers to the production of organisms from feeding on organisms not delivered from primary production. Tertiary production occurs from predation on secondary and other tertiary organisms.
Upper Watershed Processes - Fire and Erosion	Watershed processes that contribute to maintaining the health of the Bay-Delta ecosystem include fire and erosion. Water supply and water quality in the Central Valley are dependent on healthy watersheds. Land and resource management in the upper portions of tributary watersheds have substantially modified watershed processes and affected the reliability of inflows of high-quality water to the Sacramento-San Joaquin Delta and San Francisco Bay. Management activities have also affected the available capacity of reservoirs that store water for and provide flood control to downstream residents.

TABLE 4. ECOLOGICAL ZONES IN WHICH ECOLOGICAL PROCESS IMPLEMENTATION OBJECTIVES, TARGETS, AND PROGRAMMATIC ACTIONS ARE PROPOSED

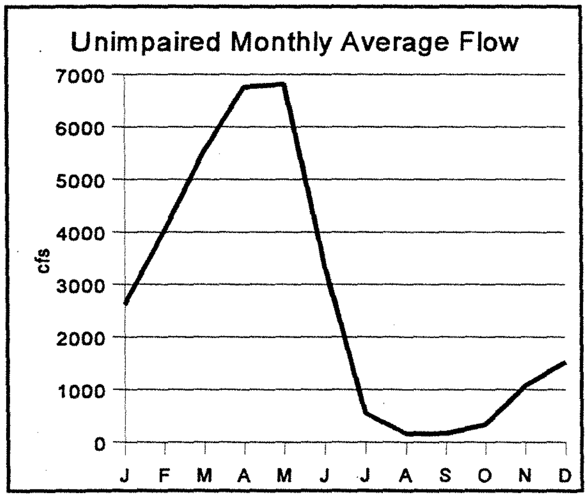
[Note: Refer to Volume II: Ecological Zone Visions for information regarding specific targets and actions.]

Ecological Process Vision	Ecological Zone[1]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Central Valley Streamflows	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Natural Sediment Supply	•		•	•	•	•	•	•	•	•	•		•	
Stream Meander			•	•	•		•	•	•			•	•	
Natural Floodplains and Flood Processes	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Central Valley Stream Temperatures	•		•	•				•	•		•	•	•	
Bay-Delta Hydraulics	•													
Bay-Delta Aquatic Foodweb	•	•												
Watershed Processes - Fire and Erosion				•	•	•	•	•	•	•	•		•	•

[1] 1 = Sacramento-San Joaquin Delta
2 = Suisun Marsh/North San Francisco Bay
3 = Sacramento River
4 = North Sacramento Valley
5 = Cottonwood Creek
6 = Colusa Basin
7 = Butte Basin
8 = Feather River/Sutter Basin
9 = American River Basin
10 = Yolo Basin
11 = Eastside Delta Tributaries
12 = San Joaquin River
13 = East San Joaquin Basin
14 = West San Joaquin Basin

INTRODUCTION

Streamflow refers to the amount of fresh water flowing in rivers and Bay-Delta channels. Central Valley streamflows are a combination of natural discharges from surface water and groundwater and managed releases from reservoirs. Streamflow varies seasonally and annually with rainfall, run-off, and water-supply management. The volume and distribution of water in the Bay-Delta and its watersheds support important ecological processes and functions. Human activities have had a significant influence on the natural streamflow pattern of the Bay-Delta and its watershed.



Unimpaired Median Monthly Average Flow in the American River below Nimbus Dam, 1962-1992

RESOURCE DESCRIPTION

California is divided into hydrologic regions which reflect runoff and drainage basins. Three major hydrologic regions are contained within the ERPP Study Area: Sacramento River, San Joaquin River, and San Francisco Bay

The Sacramento River Region contains the entire drainage of the Sacramento Valley and its adjacent watersheds and extends from Collinsville in the Sacramento-San Joaquin Delta almost 300 upstream to the Oregon border.

Characteristics of the Sacramento River Region

Average annual precipitation: 36 inches
Average annual runoff: 22,389,700 AF
Land area: 26,960 square miles
Population: 2,208,900

(Source: DWR 1994)

The San Joaquin River Region is located in the heart of California and is bordered by the sierra Nevada on the east and the coastal range on the west.

Characteristics of the San Joaquin River Region

Average annual precipitation: 13 inches
Average annual runoff: 7,933,300 AF
Land area: 15,950 square miles
Population: 1,430,200

(Source: DWR 1994)

The San Francisco Bay Region extends from Pescadero Creek in southern San Mateo County to the mouth of Tomales Bay in the north and inland to the confluence of the Sacramento and San Joaquin rivers near Collinsville.

Characteristics of the San Francisco Bay Region

Average annual precipitation: 31 inches
Average annual runoff: 1,245,500 AF
Land area: 4,400 square miles
Population: 5,484,000

(Source: DWR 1994)

The total streamflow that would occur without upstream reservoirs and diversions is called the unimpaired flow. Data on unimpaired flows provide a record of natural streamflow patterns and a benchmark for judging the effects of water management and allocation of the available runoff. Unimpaired streamflows are also influenced by the condition of the upper watersheds and their ability to moderate or intensify runoff patterns.

Streamflows in Central Valley watersheds are extremely variable. Total annual unimpaired streamflow into and through the Central Valley varies from a low of about 5 million acre-feet (MAF) to a high of about 38 MAF. Most of the flow occurs December through June. A large part of the total flow volume occurs during relatively short periods of time, caused either by rainfall or snowmelt.

Construction and operation of dams on major rivers and streams has reduced peak winter and spring flows and increased summer and fall flows. Dry year flows are higher in some streams from release of carryover storage from reservoirs. In other streams, flow may be lower because of water diversions.

Winter and spring peak flows and summer and fall base flows are important to maintain ecological processes such as sediment transport, stream meandering, and riparian habitat regeneration. Native fish and wildlife species evolved with these flow patterns. Spawning and migrating fish depend on the natural streamflow patterns. For example, Sacramento splittail spawn in winter in flooded areas provided by high flows.

The ability to restore natural streamflows is limited. Constraints include water management practices, upper watershed conditions, and previous water supply allocation (water rights and contracts). Emulating natural runoff patterns will provide the greatest potential for improving the ecological functions that are dependent on streamflow.

ECOLOGICAL FUNCTIONS OF STREAMFLOW

Streamflow can be thought of as the life-blood of the tributary watersheds that link together to form the Sacramento and San Joaquin Rivers. Groundwater and surface runoff generate flows into the stream networks in each tributary basin. Streamflow provides the geomorphic forces (energy and materials) needed to create and maintain stream channels and riparian corridors (floodplains). Streamflow controls the erosion, transport, and deposition of sediment in the stream channel and floodplain. Streamflow also transports and cleanses river gravels that support invertebrate production and fish spawning.

Natural flow patterns maintain natural sediment erosion, deposition, transport, and cleansing patterns, and thus natural stream channel and floodplain configurations. Reduced streamflow can lead to excessive sediment deposition in gravelbeds and armoring the channel with cobble.

Streamflow transports nutrients as well as dissolved and particulate organic material from rivers upstream to the Delta and estuary. These materials are important to planktonic and benthic foodweb organisms. Streamflows maintain soil moisture and transport seeds which contribute to the regeneration of riparian and riverine aquatic habitats.

Streamflow is needed to flood stream channel pools and riffles and riparian wetlands that provide habitat for fish and other wildlife. Flows transport fish eggs and larvae (e.g., striped bass, delta smelt) from spawning to nursery areas and may assist in the movement of juveniles from upstream spawning and rearing areas to the Delta (e.g., young splittail and chinook salmon).

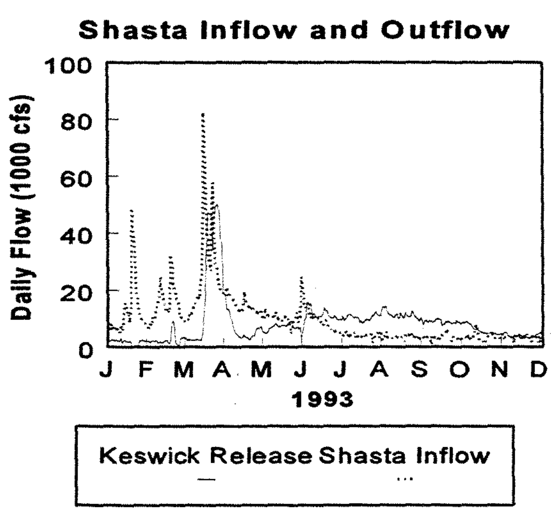
Streamflow through the Delta to San Francisco Bay is referred to as Delta outflow. Delta outflow is simply the net flow at Chipps Island. Conceptually, it is estimated as the sum of Delta inflow and precipitation in the Delta minus water use in the Delta and exports from the Delta. Delta outflow has a major influence on the tidal mixing processes and the amount of saltwater that reaches upstream into the Delta. Delta outflow controls the location of the "entrapment zone" (the area where freshwater mixes with saline water) and transports planktonic organisms, particulate organic materials, and nutrients from the rivers to the Delta and San Francisco Bay.

Following are general ecological processes and functions sustained with natural streamflow patterns:

- Channel-forming processes create and sustain the pools, riffles, meanders, sand and gravel deposits, banks, side channels, and floodplain areas. These elements are the physical framework for the stream, wetland, riparian corridor, and floodplain habitats.

- Streamflow transports nutrients and organic materials to downstream aquatic habitats where they provide the necessary components for primary (plant) and secondary (bacterial and invertebrate) foodweb production. Transport processes also move larval and juvenile fish and other aquatic organisms to downstream rearing habitats.

- Filling and flooding of channel and floodplain areas at high streamflows provide aquatic, wetland, and riparian habitat and sustain botanical processes (i.e., seed dispersal, soil moisture replenishment) within the floodplain, flood bypass, and riparian stream corridor.



HYDROLOGIC VARIATIONS

Water supplies in the Central Valley are categorized by "water-year classes" (wet, above normal, below normal, dry, and critical). This natural year-to-year hydrologic variability is used to establish water management plans. Facility operations are generally estimated using monthly rainfall and natural, unimpaired runoff conditions. Runoff is estimated from measured flows for 1922 to the present.

Seasonal variability results from rainfall events and snowmelt runoff. Rainfall events occur mainly during the "wet" season (between November and June). Substantial runoff from Sierra Nevada snowmelt extends into the summer and fall. This runoff pattern allows substantial diversion of water from Sacramento and San Joaquin River tributaries from May through September.

Central Valley reservoirs have been constructed during the last century to manage seasonal variability. Reservoirs capture winter floods and spring snowmelt (while reserving sufficient flood control storage space and maintaining minimum instream flows). This storage provides an increased water supply during summer and fall for diversions and instream flows.

MULTIPURPOSE WATER MANAGEMENT

Seasonal and annual runoff fluctuation complicates control and allocation of the available water supply. Water is allocated for various beneficial uses including flood control, water supply, power generation, and instream and other environmental flows. Priorities for streamflow management are established according to the available water supply.

Almost all major Central Valley streams are regulated by large multipurpose reservoirs (as well as smaller diversion dams) and confined by flood control levees. Many rules govern the operation of these dams and affect the overall operation of water-management systems. As the effects from these facilities on the natural runoff, sediment transport, and fish migration patterns are observed, an increased understanding of the needs for instream flows is emerging.

Recognition of the importance of streamflows to protect and promote habitat conditions for fish and wildlife populations has created conflicts between existing beneficial uses of water supply, industry, and flood control.

Several agencies may be involved in the operation of each major reservoir or diversion facility. The many rules governing facility operations have an incremental and interdependent effect on overall operation of water management systems.

WATER RIGHTS AND INSTREAM FLOW

California water rights govern streamflow allocation for beneficial uses. Both riparian and appropriative water rights exist in California. These rights are administered and monitored by the State Water Resources Control Board (SWRCB). Riparian rights support specific beneficial uses on lands immediately adjacent to the stream. Appropriative water rights allow direct diversion or storage and may be obtained for beneficial use.

Water rights are incremental, with a specific priority scheme that controls water allocation during periods of shortage. Federal courts have assigned the jurisdiction over several California streams that are used for single-purpose hydropower projects to the Federal Energy Regulatory Commission (FERC). Additional "exchange contracts" between water-rights holders and water districts or government agencies, such as the U.S. Bureau of Reclamation (Reclamation) or California Department of Water Resources (DWR) further complicate the allocation of California water supplies.

Instream flow levels are sometimes required as conditions for water quality standards, water-rights permits, and FERC licenses. Negotiated agreements between water and fisheries agencies govern minimum flows downstream of major water projects. Some streams, such as Butte Creek, are formally managed by the State watermaster agreements.

The SWRCB has included instream spring flow requirements for both Delta outflow (i.e., X2 location objectives) and the San Joaquin River at Vernalis in the 1995 Water Quality Control Plan. Instream flow requirements govern the minimum flows at specific points below diversions and are often dependent on the available water supply (e.g., water-year type). Average annual instream and spring flow requirements are generally a small fraction of natural unimpaired flow and winter releases from storage reservoirs may be much less than unimpaired flows.

Many streams have no instream flow requirements. On some streams, riparian and appropriative water rights diversions may be restricted only by an amount necessary to supply downstream users having a higher priority water right. Some Central Valley streamflows are totally depleted downstream of the major diversions during the irrigation season.

VISION

The vision for Central Valley streamflows is to restore those seasonal patterns that sustain important ecological processes, habitats, and species that depend on streamflow. Seasonal patterns of greatest importance are winter-spring rainfall or snowmelt flow events and summer-fall base flows. Restoring natural streamflow patterns will contribute to the recovery of species and overall health of the Bay-Delta.

To achieve maximum potential ecological functions and benefits from streamflows will require restoring and protecting the stream channel and floodplain process and in developing and implementing watershed management strategies and programs to protect the health of upper watersheds.

Opportunities to protect, enhance, and restore natural streamflow patterns and processes depend on stream channel and floodplain conditions, as well as existing impoundments and diversions.

Opportunities for adjusting seasonal streamflow patterns to benefit fish and wildlife while maintaining other beneficial water uses will be explored. Opportunities may include acquiring water rights from willing sellers or developing supplemental supplies (e.g., recycled water programs). Individual water rights are established according to California law, and this vision does not propose any adjudication or involuntary reallocation of water rights.

Many environmental factors and functions controlled by streamflow dynamics are only partially understood at this time. Therefore, the vision for Central Valley streamflow includes a substantial commitment to continued monitoring and evaluation of physical, chemical, and biological processes and ecological functions that are sustained and governed by streamflow.

Although the historical pattern of natural streamflows can be used as a guideline for establishing streamflow targets, the actual management of flows for each tributary or river segment will require coordination with all agencies and stakeholders. Conflicting interests and priorities will most likely be the rule rather than the exception. Streamflow targets will be developed within the existing multipurpose water resource management framework for each watershed.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

The vision for streamflow is intended to complement existing streamflow management programs. Several agencies are directly or indirectly responsible for streamflow management.

Agencies with important streamflow management responsibilities and programs include:

- U.S. Army Corps of Engineers' flood control operations of reservoirs and management of flood control facilities (e.g., levees, overflow channels and bypass weirs);

- DWR programs to provide water supplies (State Water Project), flood protection facilities, water quality monitoring, and multipurpose management of California water resources;

- Reclamation's operation of the Central Valley Project (and several other independent water projects in the Central Valley) to provide for multiple beneficial water uses, including fish and wildlife protection and habitat restoration (e.g., Central Valley Project Improvement Act);

- FERC regulation of minimum flows below hydropower projects; SWRCB administration of water rights for storage and diversions, including decisions about required instream flows for fish, water quality, and public trust resource protection;

- California Department of Fish and Game responsibility to study and recommend streamflows and temperature requirements for fish protection and propagation in streams and at hatcheries;

- U.S. Fish and Wildlife Service and National Marine Fisheries Service programs to recommend flows and other measures needed for mitigating impacts from federal projects and protecting endangered species, including the Anadromous Fish Restoration Program and the Water Management Program; and

- U.S. Geological Survey water resources division programs to measure streamflow and water quality, providing the information necessary for adaptive management of streamflows. Their monitoring and modeling activities for Central Valley groundwater and Bay-Delta hydrodynamics are also important contributions to water resources management.

Streamflows in Central Valley streams are being addressed under the Central Valley Improvement Act (CVPIA) subsection 3406(b)(2) and (b)(3) programs being administered by the USFWS. Under 3406(b)(2) 800 TAF of CVP water is to be allocated for fish and wildlife purposes. Under 3406(b)(3) additional water is to be acquired from willing sellers. The combined sources of water are to be managed under a Water Management Plan being developed for selected individual rivers under FERC licensing requirements, negotiated settlements between stakeholders and agencies, State Water Resources Control Board water rights and water quality plans, and court ordered settlements such as that for the American River (Water Forum)

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Streamflow being a primary ecosystem process is integrally linked with other processes, habitats, and species. In addition, the effects of many ecological stressors are influenced by streamflow.

In all cases, the ecological value of streamflows will be incorporated into a comprehensive adaptive management program. (Volume III contains additional information regarding CALFED's approach to adaptive management.)

This program for Central Valley streamflows will necessarily focus on the relationship of flow to the health of closely related ecological processes, habitats, and species.

Processes influenced by streamflow include:

- Central Valley water temperatures,
- sediment supply,
- stream meander corridors,
- Bay-Delta aquatic foodweb,
- floodplain and flood processes,
- groundwater/surface water interactions, and
- dilution of contaminants.

Habitats that depend on streamflow include:

- riparian,
- aquatic, and
- wetlands.

Species directly linked to streamflow include:

- anadromous fish,
- delta smelt,
- resident fish,
- riparian species,
- shorebirds, and
- waterfowl.

Each of these processes, habitats, and species are adversely affected by stressors which restrict their full function, extent, distribution, or survival. Therefore, the full ecological benefit to be derived from streamflows also depends on reduction or elimination of stressors which impair other closely related ecosystem elements. Streamflow is an important ingredient for ecological health, but cannot provide full benefit without improvement in other areas.

IMPLEMENTATION OBJECTIVES, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objectives for Central Valley streamflows are to restore basic hydraulic conditions to reactivate and maintain ecological processes that create and sustain habitat required for healthy fish, wildlife, and plant populations.

The general target for streams with large water storage reservoirs is to provide a spring flow event that emulates natural spring pulse flows in dry and normal years. For all streams provide sufficient year-round base flows to sustain important ecological processes, habitats, and species.

Actions that will contribute to restoring the ecological values of stream flow include maintaining spring flows and sustaining summer-fall base flows are the two major streamflow restoration activities considered in this vision. The following three programmatic actions will help to achieve streamflow objectives:

- Provide sufficient high flows during spring (March-May) to sustain high-flow dependent ecological functions. This can be accomplished by allowing a portion of the natural inflow to pass through large Central Valley reservoirs in spring of all but the driest years. In extreme cases, this may be accompanied by reductions in high summer storage releases.
- Maintain sufficient year round base flows to sustain aquatic streamflow dependent ecological processes, habitat, and species.
- Provide sufficient flow during the first yearly significant rain event to sustain habitat and species dependent on such flow. This can be accomplished by allowing a portion of the natural inflow to pass through large Central Valley reservoirs in all but the driest years.

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INTRODUCTION

Natural sediments of streams, rivers, and estuaries consist of mineral and organic silts, sands, gravel, cobble, and woody debris. These materials naturally enter, deposit, erode, and are transported through the Bay-Delta and its watershed. Sediment, like water, is one of the natural building blocks of the ecosystem. Many other ecological processes and functions, and habitats and species require specific types and amounts of sediment and the habitats sediments create. Gravel, for example, is important for maintaining spawning habitat for salmon and steelhead, and as habitat for stream invertebrates. Finer sediments are important in the natural development of riparian and wetland habitats. Major factors that influence the sediment supply in the Bay-Delta and its watersheds include many human activities such as dams, levees, and other structures, dredging, and gravel and sand mining.

River-transported sediments are an essential component of the physical structure and nutrient base of the Bay-Delta ecosystem and its riverine and tidal arteries. The size, volume, and seasonal timing of sediments entering the riverine and estuarine systems should be compatible with both natural and altered flow regimes. Sediment transport should match channel and floodplain characteristics of individual rivers, streams, and tidal sloughs. A specific sediment management objective is to redistribute sediment in the watersheds and valley components of the ecosystem. An appropriate level, rate, and size of sediment should be redistributed to match specific habitat requirements and ecological functions.

RESOURCE DESCRIPTION

The natural sediment supply is highly variable between the streams and tidal sloughs of the Sacramento and San Joaquin Rivers and Bay-Delta ecosystems. Part of the reason is differences in soils and geofluvial morphology of the watersheds. Other factors include difference in runoff patterns and watershed characteristics. Human activities and development may be important factors. Large dams deprive most of the major rivers entering the Sacramento-San Joaquin Valley of their primary source of sediment from the upper watersheds. Upper watershed sediment supplies have been altered by increased human use and habitation in areas previously only influenced by natural processes of fire, flood, and mass wasting.

Alluvial sediment is stored in the valley floodplains along rivers, but much of this natural supply is no longer available to rivers and streams because of extensive hardening of banks (e.g., rip-rap) to protect stream-side levees, orchards, and cropland. Some individual streams have an excess of fine sediment, such as the lower Feather River that is still affected by an oversupply of sand from the hydraulic mining era. Within the Delta, rivers and sloughs appear to suffer from a net loss of channel sediment resulting in the reduction or disappearance of midchannel islands and shallow shoal habitats. This is believed to be caused by a combination of reduced sediment supply from rivers, historic loss of Delta floodplains (reclamation of formerly extensive tule islands for agricultural uses), high velocity tidal currents, wind wave and boat wake erosion of unprotected, artificially steep banks, and channel dredging to maintain shipping routes and floodway capacity.

Land use has also altered natural sediment supplies in Central Valley watersheds. During the gold rush, natural sediment supplies in the Central Valley were greatly altered by extensive hydraulic and dredge mining on the western Sierra Nevada streams (especially the Yuba, Feather, American, lower Sacramento, and San Joaquin Rivers and their tributary watersheds). Sediment from mining in the late 19th century greatly exceeded the amounts that rivers were able to transport. Rivers became overloaded with sediment, causing deposition and flooding in valley towns and farms. Fine sediments pulsed quickly through the river systems, but the coarser sediments moved more gradually. By the late 20th century, most riverbeds had returned to pre-Gold Rush elevations because riverflows had cut through the old placer mining debris deposits stored along the banks. Some rivers and creek valleys still contain "debris dams" (e.g., Daguerre Point Dam in the Yuba River Goldfields) built a century ago in an attempt to keep placer mining sediment from spreading into streambeds of the valley and causing flooding of cities and farmlands.

Natural sediment recruitment and transport in the Central Valley are tied to streamflow. Most sediment is transported and deposited during winter and spring runoff events. Typically, bars, shoals, and braided deltas form or expand as floodwaters decline and stabilize during the dry season. Flowing water rearranges and sorts sediment (sand, silt, and clay particles) and bedload (cobble and gravel) to create the structural support for many important habitats, including fish spawning gravels, growth medium (substrate) in which riparian forests germinate and establish, and loamy floodplains that support oak woodland and grasslands. Transporting heavier cobble and gravel helps rivers dissipate stream energy, and the formation of heavy cobble bars shields the riverbed from excessive erosion and incision.

Shallow shoals of fresh sediment form along Bay-Delta rivers and sloughs by replacing sediment lost to wave action and tidal currents. The fresh sediment creates new substrate for tule marsh and sustains shallow-aquatic and tidal-mudflat habitats. Fine organic particles and suspended mineral sediment also provide essential nutrients (e.g., carbon, nitrogen, phosphorus, and iron) that support algae and phytoplankton at the base of the foodweb. High concentration of suspended sediment (high turbidity) limits growth of aquatic plants and algae by reducing sunlight penetration.

Constructed features and disturbance factors that eliminate, reduce, or alter the amount, distribution, and timing of natural sediment sources include:

- reservoirs behind medium and large dams that capture the sediment supply from the watershed;
- levees that prevent deposition of fine sediments in the floodplain alongside rivers and increase sediment scour and transport within the river channel by forcing deeper, more erosive floodflows;
- sand and gravel mining in channels and active lower floodplains of rivers and smaller tributaries that deplete the natural supply to downstream sites;
- bank protection and channelization that alters sediment transport, reduce natural bar and riffle formation, and prevent natural bank erosion and gravel and sediment releases to the river; and
- dam-regulated reduction of the magnitude and duration of average peak flows during winter and spring that reduce the ability of a river to transport bedload entering the river from tributary sources.

Sediment transport and deposition processes of the ecosystem have been significantly modified. Construction of the Sacramento River, San Joaquin River, and Delta levees and bypass systems in the early 20th century allowed Central Valley settlements and California agriculture to expand. The original levee system of the Sacramento River was built to bypass excessive floodflows, maintain sufficient channel depth for river navigation, and carry the heavy loads of sediments deposited into the Central Valley by hydraulic gold mining in the mountains and foothills.

The levees isolated rivers from their natural floodplains and separated the Bay-Delta from the extensive freshwater and saline emergent wetlands and secondary sloughs that became the agricultural "islands" we know today. River flows have sufficiently sluiced most of the sediment past the river floodplains and Delta and out to San Francisco Bay. Some of the sluiced sediment was deposited in deeper channels that now require dredging.

The natural supply of gravels and sediments entering the rivers and dams and reservoirs severely reduced streams. Construction of the State and federal dam system occurred between the 1930s (e.g., Shasta Dam) and 1970s (e.g., New Melones and New Don Pedro Dams). Although dams provide water supply and flood control benefits, they drastically reduced the natural sediment supply to Central Valley river floodplains and the Bay-Delta. Dams captured all the bedload and most of the finer sediment. Many smaller dams have filled to capacity with sediment.

The absence of sediment below dams and the confinement of rivers into narrow, leveed corridors triggered channel incision and bank erosion. Incision and erosion threatened the integrity of the levee system, leading to ongoing efforts to armor riverbanks and levees with rock riprap. Implementation of these actions further reduces the natural sediment supply of rivers.

Confining rivers and hardening banks removes the major remaining supply of gravel and sediment below dams. The lack of gravel and sediment inhibits bank erosion. Preventing or reducing bank erosion also reduces the establishment of instream woody cover (a component of shaded riverine aquatic cover) because the erosion required to topple trees into the channel no longer occurs.

The sediment deficit and high transport efficiency of the primary Delta channels, combined with wave-wash erosion, are causing the progressive disappearance of remnant tule and willow midchannel islands and shoals. These conditions prevent the replenishment of deposits that support mudflat, emergent wetlands, and willow scrub habitats. Lack of sediment and high velocities are also undermining the submerged toe of levees along Delta islands.

Immediately downstream of dams, where water temperature is often low enough to support spawning fish populations, the release or uncontrolled spills of "clean, hungry" dam water removes the spawning gravels from the channel, armors the channelbed with more resilient cobble and boulders, and erodes the fine sediment that would normally support riparian trees and shrubs along the banks. Scoured and armored river beds lack spawning habitat for salmon and steelhead forced to spawn and rear below dams that have cut them off from natural upstream habitats.

Further downstream, natural sediment and erosion patterns of the floodplain have been altered by river channelization. Only the Butte basin flood overflow area and the Sutter and Yolo Bypasses support physical sedimentation processes that roughly approximate a natural floodplain. However, flood conveyance capacity, intensive farming in the bypasses, and flood easement restrictions do not allow the remnant floodplains to support natural habitats. Floodplain habitats such as emergent marsh, cottonwood-willow riparian forest, or valley oak woodland thrive in the fine-textured alluvial deposits. A few notable natural habitats do exist. These include Sutter National Wildlife Refuge, the new Yolo Basin Wildlife Management Area, and some large privately managed waterfowl habitats in the Butte basin.

Gravel mining in Central Valley river channels has also interrupted natural sediment supplies of the rivers. Inchannel sand and gravel mining reduces downstream physical habitat and triggers incision of the channelbed both upstream and downstream. Large inchannel and low-floodplain pits are often excavated to a depth lower than the stream channel, such as occurs on the eastside tributaries of the San Joaquin River. These pits often "capture" the river. This creates additional ecosystem disturbances by trapping bedload gravel, causing the river alignment to suddenly shift, exposing outmigrating juvenile salmon and steelhead to increased predation, and trapping outmigrating juvenile salmon and steelhead in isolated backwater ponds when the river recedes.

VISION

The vision for natural sediment supply is to provide a sustained supply of alluvial sediments that are transported by rivers and streams and distributed to riverine bed deposits, floodplains, channel bars, riffles, shallow shoals, and mudflats, throughout the Sacramento-San Joaquin Valley, Delta, and Bay regions. This would contribute to habitat structure, function, and foodweb production throughout the ecosystem. Where supplies are adequate they should be protected. Where inadequate, natural supplies should be restored where possible. Where supplies cannot be restored naturally, a feasibility analysis of artificially maintaining sediment supplies will be conducted.

In specific cases natural sediment supply can be restored by removing barriers to sediment transport. A common barrier to sediment transport in Central Valley rivers are diversion dams (e.g. Daguerra Dam on the Yuba River, or the Red Bluff Dam on the Sacramento River.). In some tributary streams, small dams that no longer serve a purpose can be modified, or possibly decommissioned and removed. Dam removal allows a larger fraction of gravel to pass downstream.

Studies will be conducted to determine whether smaller reservoirs could be modified or re-operated to allow some sediment from upstream sources to pass through to the dam outlet. Sediment deposits in the upper ends of reservoirs are potential sources of sediments for introductions below dams.

In some river reaches, bank armoring could be reduced or avoided by creating unimpeded channel meander corridors using special conservation zones (e.g., erosion easements), landowner incentive programs, and strategic levee setbacks where feasible. A natural river meandering process provides much of the sediment needs of rivers.

Where channel hardening occurs downstream of major dams, sediments stored in armored banks, bars, and upper terraces can be moved into the active streambed to replace natural sediments blocked by the dams. Where bank and floodplain deposits along rivers below dams have become inactive from controlled flows, additional sediment can be recruited by restoring episodic floodflows. These floodflows must be of sufficient duration and magnitude (e.g., peak flows that occur every 1.5 to 2 years) to mobilize channelbed, bank, and bar sediments. This strategy would apply only to river systems that have an excess of stored channel deposits because of limited flood duration and magnitude below the dam. Such actions would be coordinated with project operations and aquatic species life-cycle requirements.

Wherever possible, the future sediment supply from the remaining nondammed tributaries should be declared a protected ecological resource of the river and Bay-Delta ecosystem. (Cottonwood Creek is a prime example of a nondammed tributary of the Sacramento River that contributes a significant proportion of the present natural sediment supply to the river). Effects on sediment supplies will be considered in evaluating potential new water supply and flood storage facilities as part of the Bay-Delta solution.

Further natural sediment supplies can be restored by expanding river access to historical floodplains during high flows. Floodplains provide fine particulate organic matter and small food particles. These particles will reenter the Delta and main rivers from overland flows that pass over and through crop stubble, grasslands, and riparian woodlands.

Levee setbacks, partial historical floodplain restoration (e.g., breaching diked tidelands) and selected Delta island levee removal strategies would provide new sources of sediment to the Central Valley floodplain. These measures, combined with increased channel roughness from marsh and riparian restoration projects, will increase the sediment-trapping efficiency of the Delta in sloughs and channels that are not essential for commercial ship and barge navigation.

Increasing the extent of the high-water floodplain of the Delta will reduce the potential for channel erosion, thereby reducing the rate of sediment loss from midchannel tule islands and shallow shoals. Larger floodplain areas along rivers would allow additional riparian vegetation to grow along the river floodways and would enhance the formation of bank and bar deposit habitats.

Appropriate reaches of the Sacramento, San Joaquin, Merced, Mokelumne, Cosumnes, Feather, and Yuba Rivers and other suitable streams, such as Cottonwood and Cache Creeks, will be evaluated and, where feasible, designated for eligibility as river erosion and deposition zones, or "meander belts". Meander belts will provide an area where natural erosion and sedimentation processes can occur unimpeded (within reasonable limits) to sustain a diversity of sediment-driven habitats.

In these meander belt conservation zones, some types of agricultural production could continue. Older alluvial floodplains, unlikely to be within the eroding pathway of the river within the next 20-50 years, are ideal farming lands. Farmed areas within the estimated 20-year riverbank migration corridor could be targeted for special erosion and river floodplain easements and incentive programs. Orchardists could be compensated for loss of fruit and nut trees caused by natural bank erosion, or for permanent acquisition as river floodplain conservation areas.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Protection and enhancement of sediment supplies in the rivers and Delta will involve coordination with other programs including:

- the Upper Sacramento River Fisheries and Riparian Habitat Council's efforts under the SB1086 Program,
- river corridor management plans,
- the US Army Corps of Engineers Sacramento River Flood Control and Bank Protection Projects,
- proposed San Joaquin River riparian habitat restoration and floodway management studies,
- gravel mine reclamation programs being initiated under the Surface Mining and Reclamation Act by the California Department of Conservation,
- the Anadromous Fish Restoration Program's gravel replenishment program (CVPIA Subsection 3406 b13),
- small dam removal and fish ladder rehabilitation projects, and
- local bank protection and levee construction projects.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Maintenance of natural sediment supplies in the rivers, Delta, and San Francisco Bay is closely linked to the following:

- streamflow,
- floodplain processes,
- stream meander processes,
- riparian, wetland, and aquatic habitats,

and many stressors including:

- dams,
- levees,
- bank protection,
- dredging, and
- gravel and sand mining in the floodplain.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for natural sediment supply is provide sufficient quantities to reactivate and maintain ecological processes that create and sustain habitat required for healthy fish, wildlife and plant populations.

The general targets are to conserve and augment the natural sediment supply by increasing the availability of upstream sediment sources on select streams, increasing the availability of sediment stored in banks and riverside floodplains, increasing the extent of natural stream bank erosion and channel migration, increasing the transport of sediment to the Delta and to spawning reaches of streams, increasing the deposition and stability of sediment within the Delta, and increasing the extent and distribution of shallow water habitats and tule-willow islands in the Delta.

In most cases the supply necessary to sustain functions and habitats for specific watersheds is not known. Preliminary targets for cubic yards of gravel needed below dams have been prescribed for selected rivers.

The following general approach includes actions that will sustain existing natural sediment sources and restore natural sources that no longer contribute to the sediment supply of rivers and the Delta.

- Protect existing natural sediment sources in river floodplains from disturbances such as bank protection, gravel mining, levees, dams, changes in streamflow, and changes to natural stream meanders.
- Artificially maintain sediment supplies below dams that block natural sediments in rivers.
- Increase the availability of sediment stored in banks and riverside floodplains by removing bank protection.
- Enhance and restore natural stream bank erosion and stream meander processes.

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INTRODUCTION

A "stream meander" is a dynamic natural process, and is also a term used to describe the shape of the river as a sinuous or bending wave form. Rivers with active stream channel meander zones generally support a greater diversity of aquatic and terrestrial habitat types.

Major factors that limit natural stream channel migration include construction of levees, bank riprap, channelization, upstream sediment loss from dams and levees, instream gravel mining, vegetation removal for increased floodway capacity or for reclamation of the river floodplain for agricultural uses and the storage of water and release pattern from State Water Project, Central Valley Project, and other large water development projects within the Central Valley.

Approaches to restoring more natural stream meander corridors include conserving existing river migration zones, expanding stream meander corridors, conserving upstream and bank sediment supply, and incorporating simulated flood peaks into dam water release schedules during wet years.

RESOURCE DESCRIPTION

The width and habitat patch size of riparian forest on meandering streams tend to be large and connected. The forest is always being replenished by new territory colonized by cottonwood and willow trees on recently formed point bars and floodplain deposits.

The flow velocity in meandering streams varies greatly, causing sediment and organic debris to be sorted into different sizes at different locations within the channel along a velocity gradient. Other habitat benefits from meandering streams include formation of oxbows, sloughs, and side channels that create a highly productive interaction between aquatic and terrestrial communities, (e.g., canopy shading and leaf and insect drop over the riverine aquatic bed). Therefore, many species of fish, amphibians, and insects can find suitable habitat in stream meander landscapes.

Rivers that flow through their own valley alluvium (i.e., gravel, sand, and silt deposited earlier in time) have the potential to shift position. Rivers shift position when banks erode and sediment is deposited. Bank erosion and sediment deposition, form bars that block or redirect riverflow. The bars also stimulate additional erosion as the river channel migrates away from the bar.

The following characteristics of a river increase the probability that it will change course during winter/spring flows:

- high average sediment or bedload source, erodible bank and bed deposits (e.g., sand and gravel);
- potential for extreme flood peaks, and
- a low density of mature vegetation along the channel.

Meandering streams typically support a wider corridor of natural habitats than channelized rivers. River flora and fauna are adapted to the changing, unstable nature of alluvial streams. They tolerate their stems being buried by deposits of river sediment and disperse seeds by wind and water to locations where new bars have formed. Meandering streams typically form the pool-riffle sequence that supports a range of fish habitats. The leading edge of the eroding side of the bend generates new sediment and gravel from the bank and topples riparian trees into the channel. These processes create high-quality aquatic cover and provide food and substrate for aquatic insects on which fish feed. Sediment lost at the eroding bank is transported downstream and redeposited on point bars. This process initiates the habitat colonization and bank renewal process. When pronounced bends are formed, an unimpeded river will eventually cut off the bend by eroding a "shortcut" across the inside bend during high flows. Through this process, backwater swales and oxbow lakes are formed, providing important juvenile fish rearing areas and sources of foodweb production.

Rivers with armored banks (rock riprap) or naturally stable stream channels are more likely to have urban or agricultural land use encroach into the riparian floodplain and forest. This encroachment often leaves room for only a narrow band of trees or shrubs along the bank and results in low habitat quality for fish and wildlife. Alluvial rivers with artificially hardened banks and static channels suffer a general loss of diversity and quality at the interface of aquatic and terrestrial habitats. Unfortunately, making rivers more predictable has led to a decline in river ecosystem quality because the species and habitats that evolved on rivers are dependent on the changing, natural disturbance cycles of meandering streams.

All Central Valley streams have been affected by stressors that diminish stream meandering and associated aquatic and riparian habitats. However, significant reaches of several large rivers still support full or partial characteristics of a dynamic stream meander pattern. The best example in California is the Sacramento River between Red Bluff and Butte City. Other important examples include the San Joaquin River (from Mossdale to Merced River); the Merced, Tuolumne, Cosumnes, Feather, and Yuba Rivers; and Cottonwood, Stony, and Cache Creeks.

Natural meander belts tend to be the least affected where there are no major levees or where levees are set back several hundred feet from the main channel bank; on rivers that have high flow stage during frequent flood peaks, thereby discouraging land conversion to urban or agricultural uses; and on rivers with floodplain soils that are not conducive to high-yield crops or orchards (e.g., saline hardpan soils along the lower San Joaquin River or gravelly, barren floodplains along the Yuba River).

To support a natural, dynamic stream meander system, the following important characteristics are needed, and identified stressors must be overcome or compensated for:

- A supply of gravel and sediment that matches the net transport and displacement of channel sediment and bedload. Dams interfere with the natural sediment supply from upstream, while levees, instream gravel mining, and bank protection projects deplete channel and floodplain sediment supplies. Most of the major tributaries of the Sacramento and San Joaquin Rivers have large dams above an elevation of 300 feet. Most of the length of these rivers in the valley floor are being mined or have been mined for gravel, and all are confined by leveed and incised channels along substantial portions upstream of the Delta.

- A series of periodic flood peaks sufficient magnitude and duration to remobilize and rearrange gravel and cobble deposits, transport sand and fine sediment to form new or expanded point bars, and erode banks or low bars on outside bends. Dam releases typically tame flows or eliminate flood peaks in dry or normal years. Tamed flows reduce bedload transport capacity while increasing base flows during summer. Channelization and levee confinement cause high flows to become deeper to compensate for less floodplain width, resulting in artificially increased sediment transport capacity. This reduced capacity prevents sediment capture in the offchannel floodplains and removes sediment from shallow shoal and bar deposits. The absence of frequent high-energy flows also prevents the scour of riparian vegetation, reducing the rate of natural sediment and cottonwood regeneration.

- Dense vegetation occupying the channelbanks and adjacent low floodplains to stabilize the river planform (i.e., modulate the annual rate of bank migration), reduce riverflow velocities to cause new sediment to aggrade on bars, build topsoil in higher floodplains, and provide shade and instream woody cover to the aquatic zone. Narrow channels created by levees set too close to the low-flow shoreline separate the river from its floodplain and leave little room for riparian vegetation. Bank protection eliminates or reduces vegetation on outside bends. Channel hardening discourages both erosion and point bar formation, resulting in a static, similarly-aged stand of riparian forest and a narrowing or discontinuity of the riparian cover. Artificially narrowed channels may require periodic vegetation removal to maintain minimum floodflow capacity and are more likely to require expensive bank riprap to protect the vulnerable levees during high flows.

- Adequate floodplain width to absorb and pass out-of-bank flows (i.e., the natural flood stage), capture fine sediments, store and filter woody debris, and, most importantly, make room for the progressive meander migration of the river channel within its floodplain. Loss of river floodplain functions has converted dynamic riverine ecosystems to static conveyance facilities for the transport of irrigation and drinking water and floodflow management. Urban encroachment in floodplains and meander belts usually follows river confinement and bank hardening.

- Development of innovative means to meet local or riparian water supplies without the need to install bank protection for diversion points. Creation of these hard points to protect diversions also impairs natural stream migration. In general, diversions situated within designated stream meander zones should be modular and designed to be removable to accommodate stream meander.

In general, the loss of river meander potential and functions in the Central Valley has resulted in more sterile river ecosystems upstream of the Delta. Supports less habitat for anadromous and resident fish and provides less nutrients and food to the Delta.

VISION

The vision for stream meander is to conserve and reestablish areas of active stream meander by implementing stream conservation programs, setting levees back, and reestablishing natural sediment supply to restore riverine and floodplain habitats for fish and wildlife.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Ecosystem Restoration Program Plan (ERPP) efforts may involve cooperation with other programs and organizations. These include:

- Upper Sacramento River Fisheries and Riparian Habitat Advisory Council (SB1086) group efforts and river corridor management plans implemented for the Sacramento River (Resources Agency 1989);

- U.S. Army Corps of Engineers' proposed reevaluation of the Sacramento River Flood Control Project and ongoing Bank Protection Project, including more comprehensive floodplain management and river ecosystem restoration opportunities;

- proposed riparian habitat restoration and floodplain management studies for the San Joaquin River, including potential new flood bypass systems and expanded river floodplains on lands recently acquired by the California Department of Parks and Recreation and U.S. Fish and Wildlife Service (USFWS);

- Anadromous Fish Restoration Program gravel replenishment programs and plans and small dam removal and/or fish ladder rehabilitation projects;

- The Nature Conservancy's ongoing

Sacramento Valley conservation planning; expansion plans being made for the Sacramento River National Wildlife Refuge (USFWS) and California Department of Fish and Game's Sacramento River Wildlife Management Area;

- The Cosumnes River Preserve which is a joint project of The Nature Conservancy, Department of Interior, Department of Water Resources, Department of Fish and Game, Wildlife Conservation Board, and others.

- Plans for the San Joaquin River Parkway; plans being put into effect for all county-sponsored instream mining and reclamation ordinances and river and stream management plans; and reclamation planning assistance programs being initiated under the Surface Mining and Reclamation Act by the California Department of Conservation.

- The Riparian Habitat Joint Venture which promotes the coordinated development of riparian restoration plans with the primary purpose of conserving migrant land birds.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Health stream meander corridors are dependent on the following ecological processes:

- Central Valley streamflows,

- Natural sediment supplies, and

- Natural floodplains and flood processes.

Habitat supported by healthy stream meander corridors are primarily related to riparian and riverine aquatic habitats.

Many fish, wildlife, plant species, and plant communities are dependent on the riparian zone associated with stream meander corridors.

Stressors that impair the health of stream meander corridors include:

- Dams, reservoirs, weirs, and other human-made structures;

- Levees, bridges, and bank protection;

- Gravel mining;

- Invasive riparian plants; and

- Wildfires in the riparian zone.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for stream meander corridors is to maintain, improve, or restore natural stream meander processes to allow the natural recruitment of sediments, create habitats, and promote riparian succession.

The general targets and actions which will contribute to restoring healthy stream meander corridors include the following.

EXISTING RIVER MIGRATION ZONES

Appropriate reaches of the Sacramento and San Joaquin Rivers and their major alluvial tributaries will be evaluated. Suitable portions will be designated as important river migration and floodplain deposition zones, or "meander belts." In these zones, natural erosion and sedimentation processes occur or could potentially occur unimpeded (within reasonable limits), sustaining a diversity of sediment-driven habitats.

These river reaches and potential meander zones will be eligible for river conservation programs and appropriate landowner incentives once they have been evaluated and ranked according to ecological process and function characteristics. Remaining Central Valley stream reaches where natural meander processes occur will be mapped and ranked according to the level of meander-system functions, the quality of dependent habitats, and the contribution to Delta species and important physical processes.

STREAM MEANDER CORRIDORS

Levees and floodplains along rivers of the Sacramento and San Joaquin Valleys will be evaluated to determine if some levees can be set back to create new meander corridors or nodes of expanded floodplains and wider riparian forest. This approach also benefits flood safety and reduces flood protection maintenance costs by repositioning levees outside the primary bank migration pathway of alluvial streams, reducing the need for expensive rock riprap, and reducing the potential for levee breaches. Enlarging inadequate floodplains will increase the volume of safe floodflow, while allowing additional riparian vegetation within the channel to close gaps in the forest canopy. Riparian vegetation will tend to naturally recolonize stream meanders in areas where the channel is widened because point bar development and sediment capture will be enhanced. Vegetation removal practices, required in confined channels, are reduced with levee setbacks. The Sacramento River between Chico Landing and Colusa is an example of a partial levee setback that benefits both flood safety and habitat quality while reducing levee and channel maintenance costs.

In other areas, land use changes and land management costs in floodplains outside existing levees may no longer justify continual levee upkeep and future bank protection costs. These areas present additional potential for expanded river meander zones. Levees could be removed, breached in key locations, or allowed to gradually erode from river migration processes. An example is the floodplain of the lower San Joaquin River near Los Banos, where former livestock pasture has been acquired for wildlife management as part of the San Luis National Wildlife Refuge. Another example is north Delta islands, where land subsidence and frequent levee failures have diminished the value of farmed land.

UPSTREAM AND BANK SEDIMENT SUPPLY

The first step in restoring upstream and bank sediment supply is to identify and rank the sediment contribution of remaining nondammed tributaries of alluvial rivers. These tributaries help support the dynamic equilibrium of meandering stream corridors and spawning gravel areas. River reaches where bank and floodplain gravels and sediment deposits are, or could reasonably be made, available to meandering rivers through natural erosion processes must also be identified. A variety of approaches will be needed to ensure that these remaining river sediment supply sources are conserved.

The potential ecosystem benefits of county mining ordinances which incorporate incentives and policies that promote replacing instream gravel mines with offchannel mines in high terrace deposits, abandoned dredger tailings, and reservoir Delta deposits should be evaluated. The objective is to phase out instream gravel extraction that disrupts natural meander geomorphology and depletes annual sediment supply.

DAM RELEASE SCHEDULES DURING WET YEARS

The potential for modifying reservoir storage management during wet years will be investigated. Releases during wet years could simulate the seasonal pattern of natural, short-duration flood peaks. The magnitude and duration of major natural flood peaks cannot be restored in rivers below large reservoirs, but even short duration high flows can contribute significantly to the physical forces that support meander formation. This was demonstrated by the experimental flows released on the Colorado River below Glen Canyon Dam, which redistributed channel sediments from tributaries to create new fish habitat and substrate for riparian vegetation. Dam releases can be combined with nonregulated tributary inflow below the reservoirs to create flow spikes of sufficient magnitude to mobilize bed and bank sediments, clean spawning gravels, and form new river corridor landforms.

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NATURAL FLOODPLAINS AND FLOOD PROCESSES

INTRODUCTION

Floodplains and flood processes provide important seasonal habitat for fish and wildlife, and provide sediment and nutrients to both the flooded lands and aquatic habitats of the rivers and Bay-Delta. Flooding also shapes the associated plant and animal communities. Major factors that reduce floodplain and flood processes contributions to the health of the Central Valley rivers and the Bay-Delta include construction of levees that constrict the floodplain, dams and reservoir operations that moderate flows, and activities that maintain flow capacity in major flood bypasses.

Before reclamation, Central Valley rivers and the Bay-Delta were comprised primarily of tidal and riverine floodplains in the form of vast tule islands, perennial grasslands, and riparian fringe corridors, intersected by permanent open water channels and secondary sloughs. Today only the primary open water channels remain, bordered by narrow, steep-sided floodplains sandwiched between the channel and the levee. Floodplains of the Bay-Delta provided a matrix for the interaction of secondary channel shorelines with tule marsh, riparian scrub, grasslands, and intertidal community types. Floodplains are essential to a balanced sediment budget by providing an area having lower velocity than the main channel, thereby capturing fine sediment and organic debris, and providing a more stable substrate for many vegetation types to flourish. During winter and spring flood events, floodplains provide important velocity refugia for resident and anadromous fish.

Floodplains reduce flood stages by slowing flow velocities, moderate channel incision and scour by providing a wide area for bank overflow, contribute to species diversity by creating the landforms that support different communities, contribute to the aquatic foodweb when overbank floodflows collect and transport organic matter from the floodplain back to channels and eventually the Bay-Delta estuary, provide low-velocity refuge for fish and other aquatic organisms during floods, and provide spawning habitat for fish species dependent on the Bay-Delta. Major factors that have disrupted floodplains and flood processes in the Delta and its tributaries include construction of levees that constrict the floodplain, dams and reservoir operations that moderate flow and block sediment, and activities that maintain flow capacity in major flood bypasses. Approaches to restoring more natural floodplains and flood processes include conserving existing natural floodplains and expanding confined floodplains.

RESOURCE DESCRIPTION

A natural floodplain is an important component of rivers and estuaries that allows many essential ecological functions to occur. Healthy floodplains are morphologically complex, including backwaters, wetlands, sloughs, and distributaries that carry ans store floodwater. Floodplain areas can constitute islands of biodiversity within semi-arid landscapes, especially during dry seasons and extended droughts. The term *floodplain* as used here means the generally flat area adjoining rivers and sloughs that is flooded by peak flows every 1.5-2 years and exceed the capacity of the channel ("bankfull discharge"). Peak flows in winter and spring that happen every 1.5-2 years are considered by river geomorphologists to be the "dominant discharge" that contributes the most to defining the shape and size of the channel and the distribution of sediment, bar, and bed materials. Larger flood events can cause major changes to occur, but they do not happen often enough to be the decisive factor in river geomorphology.

A more common use of the term *floodplain* refers to the 100-year floodplain as determined and mapped by the U.S. Army Corps of Engineers (Corps) and Federal Emergency Management

Agency (FEMA). This definition is used to prepare land-use and flood-management plans.

Active floodplains provide many ecological benefits by:

- Slowing flow velocities
- Moderating channel incision and scour by providing area for bank overflow
- Contributing to species diversity by creating landforms that support different communities
- Contributing to the aquatic foodweb by collecting and transporting organic matter from the floodplain back to channels and eventually the Bay-Delta estuary
- Providing low-velocity refuge for fish and other aquatic organisms during floods
- Providing spawning habitat for fish species dependent on the Bay-Delta.
- Providing habitats for wildlife such as shorebirds and dabbling ducks, and in high rainfall years, diving ducks.

One benefit of levees and flood control reservoirs is reducing the extent of and hazards within the 100-year floodplain and similar high-magnitude, low-probability storm events, as experienced in the January 1997 flood. The 100-year floodplain is related to a natural river floodplain but does not apply to the following discussion of ecosystem functions as supported by flood processes. A predicted 100-year floodplain covers a much larger area than a natural floodplain of a river, slough, or stream at bankfull discharge.

At higher flow, water spills out of the channel and flows over the flat-lying land near the river. River channels are not large enough to accommodate higher discharges without overflowing. This process of out-of-bank flow is a common but little recognized attribute of rivers and their floodplain.

Levees placed close to riverbanks have allowed human encroachment on river floodplains. Human encroachment on the floodplains of rivers accounts for the predominance of flood-related damage. Central Valley rivers that have little or no remaining natural floodplain, typically have the lowest ecological values and present the greatest risk of flood damage to adjacent lands. Large-scale reclamation and separation of low-lying land alongside rivers, streams, and estuaries have eliminated major habitat areas including riparian forests, marshes, and upper tidal zones.

On many tributaries, large reservoirs and diversions have also reduced the size of natural floodplains. Reservoirs and diversions reduce the frequency and duration of bankfull discharge and restrict channel flow to the low-flow channel most of the time, including during the wet season. In this case, a stream no longer comes into contact with its floodplain except during high-magnitude, low-frequency flood events. These types of streams may experience channel straightening and incision. The reduction of flood frequency on the lower floodplain often encourages encroachment of agricultural land uses and even recreational development on the area that once supported diverse floodplain habitats.

Floodplains reduce flood stages in the Delta, rivers, and streams by increasing the cross-sectional area of the channel and slowing flow velocities. Under overbank flow conditions, the river merges with its floodplain, increasing the capacity of the river to move and temporarily store large volumes of storm flow. Slow-moving water covering large riverine floodplains and adjacent basins naturally detains the volume of floodwaters entering the Delta and leveed reaches of the lower Sacramento and San Joaquin Rivers. Temporary floodplain storage thereby reduces the peak stage of flood events in the Delta region and other sectors of the levee system, and gradually releases the storm water as flood waters recede. The prolonged inundation of floodplains, such as can be observed in the Yolo and Sutter Bypasses and Stone Lakes basin, is highly compatible with the natural flood tolerance of seasonal wetland and riparian vegetation and animal life.

Floodplains capture and store sediment, build soil, and reduce the need for dredging channels downstream and in the Delta. The overbank flow across a floodplain is wider and more shallow than in the channel. The flow often encounters more resistance from vegetation along the outer banks, which causes the river to lose energy in the floodplain areas and, in turn, causes sand and fine sediment to be deposited. Natural levee mounds parallel the channel banks are created by the deposited sediment. The sediment also builds soil to support forests and grasslands. Natural floodplains are thus able to capture and store enormous volumes of fine sediment spread over large areas, balancing the river's sediment budget and preventing the clogging of channels and estuaries downstream.

Floodplain overflow moderates channel incision and bank scour. The term *stream power* refers to the ability of riverflow to erode the bed and bank by the shear stress created by deep, high-velocity, turbulent water. Rivers and streams confined to a narrow channel by bedrock canyon walls or constructed levees have greater stream power than alluvial rivers with unconfined adjoining floodplains. Energy and flood volume diverted into the overbank floodplain regulate the stream power acting on the channelbed and banks and, in concert with the binding effect of shoreline vegetation, prevent channel instability. Stream meander moderates the rate of change. Although many rivers and streams tend to experience some bed incision during high winter flows, the floodplain overflow capacity moderates stage increases and channel velocities that would otherwise cause excessive channel incision and widespread loss of riparian vegetation and riverine bed habitats during major storm events. Wide floodplains also reduce the scour effects on levees and bridge piers during high flows.

Floodplains contribute to habitat, and therefore, species diversity. During bankfull discharge, a flow/energy gradient exists from the channelbanks to the outermost extent of the natural floodplain. The flow/energy gradient results in a corresponding gradient from larger to smaller particle deposition and greater to lesser frequency of inundation. Scour effects are also greatest nearest the channel banks. The build-up of natural levee mounds and ridges may trap floodwaters in shallow, marshy basins formed between the outermost high ground and the sediment ridge deposited alongside the channel. These physical processes combine to create highly variable vegetation community types and age classes over the floodplain surface. The variation in plant species and community structure provides a wide array of habitat types and interfaces, resulting in the notably high wildlife species diversity found in riverine and estuarine corridors.

Floodplains are a major source of nutrients and organic matter for the aquatic zone. Floodwater passing over flat-lying lands captures organic material, carbon and nutrient-rich soil particles, insects, and fallen trees. These materials are transported at high flow stage to backwater basins, estuaries, and secondary channels that may then return the organic "cargo" to the river and Delta aquatic zone. These organic components provide microhabitats, prey items, and nutrients that sustain zooplankton, aquatic invertebrates, and small fish in the rivers and Delta.

Organic debris and dislodged trees may be captured by the filtering effect of the floodplain during one year, forming debris piles as floodwaters recede, and then be resuspended or swept away by a subsequent inundation of the floodplain. Without a floodplain to cycle buoyant matter conveyed by rivers and streams at high flow, most of the organic matter generated would be flushed through the system without being fully used. By detaining floodwaters longer than in the main channels, floodplains increase the residence time of nutrients, phytoplankton, and zooplankton, which promotes greater energy use and higher productivity of the foodweb entering the Delta.

Floodplains provide safe haven and spawning areas for native Delta and valley fish species. Fish, especially juveniles, seek lower velocity refuge from turbid, turbulent floodflows in rivers and streams. Vegetated floodplains adjoining channels provide ideal velocity refuge and overhead and instream cover during high-flow events. Here, small juvenile salmon, steelhead, and resident native fish can avoid excessive predation and weather the inhospitable stormflows in the main channel. Some fish species important to the Delta, such as splittail, will disperse from the rivers and sloughs into shallow, vegetated floodplains to spawn. Splittail recruitment is highest during wet years when the floodplains of the Delta and rivers, such as the lower Yolo basin, are flooded for a long time.

Floodplain function is affected by a number of common and widespread stressors, including levees and dams,. Levees restrict the width and extent of floodplains in rivers and the Bay-Delta. In some areas, levees are only slightly wider than the channel at low flow, such as along the Sacramento River downstream of Colusa. Restricted floodplains typically cause deeper flow and faster channel velocity during high stage. They also restrict the amount and width of allowable or potential riparian vegetation, and have a low ratio of shallow-water habitats to deep, open water. Channels in these areas typically have a trapezoidal section, rather than a more natural compound channel with low bank angles and one or more flat-lying floodplain surfaces. Under these conditions, channels typically have a high depth-to-width ratio which is inherently unstable during high flows that can remobilize deep layers of channel bed materials. The physical processes necessary to sustain floodplain habitats may be absent or diminished. Within the Delta and Suisun and San Pablo Bays, levees restrict the extent of tidal floodplains inundated by higher high tides and storm flow surges passing through Delta sloughs and rivers.

Narrow floodplains along streams limit natural floodplain vegetation. Along rivers and streams contained within levee systems, the width of the floodplain is restricted, and much of the remaining floodplain surface has been reclaimed for orchard and cropland. Floodplain narrowing and conversion to cropland provides less inundation of vegetated areas during normal high water events, thereby reducing the input of critical nutrients and organic materials that typically come from a natural wide floodplain, and limiting rearing and spawning habitat for native fish such as splittail. In other cases, riparian vegetation is removed from the floodplain to optimize flood conveyance capacity if it is assumed that the predicted 100-year flood or "design flow"event will exceed the capacity of the channel.

Dams and reservoir operations reduce the natural peaks of a typical flood flow pattern, thereby reducing inundation of the natural floodplain. Large reservoirs on most of the Sacramento and San Joaquin Rivers tributaries capture the 1.5- to 2-year bankfull discharge. Water releases from reservoirs limit the magnitude, frequency, and duration of higher channel-forming flows that would otherwise spread into the lower floodplain areas adjoining rivers. Reservoirs also capture most of the incoming fine sediment that is needed to build soil on the floodplain. The net effect is to convert rivers and streams below dams into much smaller versions of the original channel and floodplain.

Managed reservoir releases may not be sufficient to interact with the remaining patches of floodplain except during higher magnitude stormflows. This is especially true on rivers such as the American River, where there are no major nondammed tributaries downstream of Folsom and Nimbus Dams. Channel incision that often follows dam construction and associated loss of the natural sediment supply further exacerbates the shrinkage of the floodplain alongside the lowered channel.

Flood management programs and policies affecting the Sutter and Yolo Bypasses discourage vegetation in the floodplain. Although the Yolo and Sutter Bypasses provide some of the physical functions of natural flooding and floodplain benefits, the full ecological potential of the floodplain is not realized because of the artificially uniform grade and generally sterile, nonvegetated condition of most of the bypass system. As recently as 1960, there were still hundreds of acres of natural grassland and valley oak woodland in the bypass system, most of which have been removed to improve floodway conveyance and make way for more intensive cropping patterns.

VISION

The vision for natural floodplains and flood processes is to maintain or restore the processes that sustain them by conserving existing intact floodplains and modifying or removing barriers to overbank flooding to reestablish aquatic, wetland, and riparian floodplain habitats.

Measures for conserving and enhancing natural floodplains and flood processes are complimented by the visions for natural sediment supply, natural fluvial geomorphology, and stream meander corridors. If the floodplain, meander width, sediment supply, and natural or simulated flood peaks are in place, the river will respond by creating natural landforms. These natural landforms will support self-sustaining vegetation communities and aquatic and terrestrial habitats. Even partial restoration or simulation of natural physical processes and floodplains will enhance channel characteristics and resultant habitats.

Conservation and management of natural existing floodplains should be promoted. Cooperative efforts with the U.S. Army Corps of Engineers and California Department of Water Resources (DWR) should be developed to map and describe the hydrologic characteristics and conditions of all remaining natural riverine and estuarine floodplains not separated from channels by levees or irreversible stream incision. Remaining floodplains that interact with bankfull discharge and higher high tides should be maintained as active floodplains because of their ecological functions and habitat potential, as well as their flood management benefits.

Flood processes and floodplain functions can be restored to many rivers, streams, and estuaries where levees are no longer essential for flood safety or where agricultural uses are marginal or problematic because of poor drainage, high maintenance costs, or frequent sand deposition.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Attaining the vision for natural floodplains and flood processes will involve coordination with other programs and organizations, including:

- Upper Sacramento River Fisheries and Riparian Habitat Advisory Council (SB1086 group) efforts and river corridor management plans implemented for the Sacramento River;
- studies underway by the state Reclamation Board and DWR to evaluate the aftermath of the January 1997 flood damage, levee stability, and future floodplain risk assessment;
- the U.S. Army Corps of Engineers' planned reevaluation of the Sacramento River Flood Control Project and ongoing Bank Protection Project, including more comprehensive floodplain management and river ecosystem restoration opportunities;
- proposed riparian habitat restoration and floodplain management studies for the San Joaquin River and its major tributaries, under supervision of the State Reclamation Board and Corps of Engineers, including potential new flood bypass systems and expanded river floodplains on lands recently acquired by the California Department of Parks and Recreation and U.S. Fish and Wildlife Service (USFWS);
- the San Joaquin River Parkway Plan;
- various plans for the restoration of tidelands (i.e., tidal floodplains) in the north San Pablo Bay and Suisun Bay; and
- multiagency plans or studies to breach levees and reopen floodplains of islands of the north Delta, including Liberty and Prospect Islands, and Little Holland Tract.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Maintenance of natural floodplain and flood processes in the rivers and Delta is closely linked with stream flow, sediment supply, and stream meander processes, riparian, wetland, and aquatic habitats, and many stressors including dams, levees, bank protection, dredging, and gravel and sand mining in the floodplain.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for natural floodplains and flood processes is to modify channel and basin configurations in order to improve floodplain function along Central Valley rivers and the Bay-Delta.

General targets to restore health to floodplains and flood processes include:

- conserving and expanding floodplains of Central Valley rivers and Bay-Delta by augmenting the natural flood processes including increasing the average floodplain width and linear extent of low areas beyond channel banks subject to bankfull discharge;
- promoting flood detention in flood basins and, where appropriate, encouraging wetland formation,
- increasing the frequency of inundation of vegetated floodplains connected to rivers and tidal channels; increasing the extent of tidal inundation at or above mean high tide; and
- reducing the extent of trapezoidal channels within levees and floodways; and increasing the acreage and connectivity of natural habitat areas within active floodplains of rivers and estuaries.

Floodplain expansion can be implemented in one of the following ways:

- Set back levees along channels and tidal sloughs to expand the width of the river's floodplain within the levee system. This approach should be evaluated on many rivers and tributaries as part of the overall reevaluation of the valley's flood control infrastructure and floodplain management policies.
- Acquire flood easements on agricultural and natural lands to allow a greater frequency and extent of floodplain inundation.
- Breach or remove levees from channels that are confined by narrow levee corridors, where feasible. In farmed areas, much of the land could continue to be farmed, if desirable, because most flooding would occur in limited areas and only during the non-growing season. This approach may have wide applicability to the low-lying plains of the San Joaquin River and lower tributaries and should be studied together with levee upgrades.
- Modify bypass and channel vegetation management policies to allow greater vegetative cover on existing floodplains. Where needed, compensate for increased channel roughness by implementing other flood control projects upstream that reduce peak flood water surface elevations.
- Expand floodplains and bypasses and add additional flood relief structures to reduce maximum flood stage in the channels. Expanded floodplains will allow for more vegetation and habitat within the channels, as well as the potential to provide greater flood protection. The Corps of Engineers and the Governor's Flood Control Task Force will be evaluating the need for new flood relief structures for the Sacramento and Feather Rivers along the Colusa Basin and Sutter

Basin and for the San Joaquin River and lower tributaries along the extensive historic river plains.

- Breach or remove levees along Delta sloughs and former diked tidelands of the Bay.

INTRODUCTION

Water temperatures in Central Valley rivers and streams and in the Bay-Delta are determined by the natural heating and cooling process of water bodies. Water temperature is controlled by water source (i.e., dam releases, runoff, and discharges), surface water and groundwater inflow, geomorphology (e.g., depth), tides, riparian shading, water clarity, and, most often, air temperature. Water temperature is a major factor in habitat suitability for aquatic organisms. Unnaturally high water temperature can become a stressor to many aquatic organisms.

Major factors that limit water temperature contributions to the health of the Bay-Delta are disruption of historical streamflow patterns, loss of riparian vegetation, stored water releases from reservoirs, and discharges from agricultural drains.

RESOURCE DESCRIPTION

Natural biochemical processes, as well as aquatic organism physiology and behavior (e.g., respiration, feeding, growth), are partially controlled by water temperatures. Many native aquatic organisms, such as chinook salmon, depend on cool water for spawning, rearing, and migrating. For example, adult salmon migrating upstream through the Delta and into the rivers are stressed when water temperatures reach into the 58 to 65° Fahrenheit (F) range, which may delay migration and spawning, which in turn may affect sport fishing and potentially production of juvenile salmon.

High fall water temperatures in the Delta may delay upstream migration of fall run chinook salmon from the Bay into and through the Delta. High spring water temperatures in the rivers and Delta may stress young chinook salmon migrating downstream to the ocean. High summer water temperatures in the Sacramento River near Redding may stress the eggs and fry of winter-run chinook salmon. Unusually high water temperatures in periods of drought were primary factors in historical declines of salmon and other fish species.

Although stream temperatures fluctuate daily, seasonally and in response to meteorological conditions (e.g., air temperature and the amount of sunshine), many important ecological functions are dependent on a relatively narrow temperature range. For example, salmon and steelhead require 54°F to 57°F to spawn and eggs require water temperatures below 57°F. Growth of young salmon and steelhead is generally optimal in the 50-60°F range.

Stream temperatures regulate important ecosystem functions including:

- Algae blooms,
- Aquatic invertebrate reproduction and growth,
- Fish migration,
- Fish spawning,
- Fish development and growth,
- The general well-being of aquatic organisms,
- Metabolism and behavioral cues of aquatic organisms,
- The amount of dissolved oxygen (DO) available in the water body, and
- Rates of organic material decay and nutrient recycling in aquatic habitats.

The ability to control water temperature in rivers and the Delta is limited because water temperature is most strongly influenced by air temperature. Some temperature regulation is available through control over streamflows, discharges of warm water into rivers and the Delta, and the extent of inundation and shading of floodplains. Temperature can be controlled to some extent below major Central Valley reservoirs by the selective release of warm or cold water from different depths behind the dams.

Construction and operation of Shasta Dam dramatically altered the flow regime and thermal characteristics of the Sacramento River (Hallock 1987). Hallock observed that water released in the spring was often too cold for rapid growth of juvenile fall- and late-fall-run chinook salmon, and that water released in August and September was often too warm for successful spawning and incubation of spring- and winter-run chinook salmon eggs and alevins.

The Shasta Dam Temperature Control Device allows operators to release water from different depths or combinations of depths to regulate the temperature in upper portions of the lower Sacramento River. Intake shutters on Folsom Dam allow water to be released from three different layers into the lower American River. Most large reservoirs have only one deep water intake in the cold water zone of the reservoir. The amount of cold water that can be released from Central Valley reservoirs is limited, especially in drought years.

Temperatures in Central Valley streams follow a seasonal pattern. Water temperatures are controlled primarily by meteorological conditions (indicated by air temperature fluctuations). Although Central Valley air temperatures range from 30°F to over 100°F, stream temperatures generally range from about 40°F to 80°F. Coolwater fish generally require stream temperatures lower than 65°F. Lower temperatures are easily achieved in high mountain streams but are more difficult to maintain in streams at lower elevations and along the valley floor. Releases from major reservoirs and groundwater (e.g., springs) are two important seasonal sources of cool water.

Maintaining cool water below reservoirs is especially important because salmon and steelhead are blocked from reaching their historic spawning and rearing grounds in headwaters in these rivers.

The water from many Central Valley streams is impounded by large multipurpose reservoirs (as well as by smaller diversion dams) that limit the upstream migration of anadromous fish into higher elevation tributaries historically used for spawning and rearing. The operations of these reservoirs can be used to maintain adequate stream temperatures in the segments immediately downstream of the reservoirs, but these temperature control operations must be integrated with other water management objectives.

Stream temperature is a major habitat condition that exerts a strong influence on many biochemical processes. Temperature controls the maximum concentration of DO in water. Fish and other aquatic organisms require adequate amounts of DO in water to survive. The maximum DO concentration is higher at 50°F than at 70°F. Higher temperatures also increase the decay of oxygen-consuming organic materials further reducing total DO concentration.

Many fish behavior and physiological functions, such as spawning, are controlled by temperature. Fall-run salmon begin to spawn when stream temperatures fall to 60°F. Salmon-egg survival is a strong function of temperature, declining to near zero at temperatures greater than 62°F. Successful holding of adult winter-run and spring-run salmon until spawning requires temperatures below about 60°F. Temperatures below 65°F are considered necessary for successful steelhead rearing.

The Sacramento River Winter-run Chinook Salmon Recovery Team reported that water temperatures in the upper Sacramento River result from the complex interactions of: (1) ambient air temperature, (2) volume of water, (3) water temperature at release from Shasta and Trinity dams, (4) total reservoir storage, (5) location of reservoir thermocline, (6) ration of Spring Creek Powerplant releases to Shasta Dam release, and (7) tributary inflows (NMFS 1997).

Splittail trawl catches in Suisun Marsh are highest in summer when salinities are 6 to 10 parts per thousand and water temperatures are 59 to 73°F (U.S. Fish and Wildlife Service 1996).

Wang (1986) reported that delta smelt spawn in fresh water at temperatures of 44 to 59°F. In recent years, ripe delta smelt and recently hatched larvae have been collected at temperatures of 59 to 72°F, so it is likely that spawning can take place over the entire 44 to 72°F range (U.S. Fish and Wildlife Service 1996).

Cool temperatures also affects the growth rate of fish. For example, at 50°F, about 100 days are needed for rearing juvenile fall-run salmon to a size suitable for outmigration (3 inches). Rearing at 45°F would require about 140 days; rearing at 55°F would shorten the growth period to about 80 days. Fish spawning in different streams will, therefore, have different timing and duration for spawning, growth, and migration.

Hatchery temperature objectives are often targeted to provide maximum growth without increasing mortality from excessive rates of respiration and diseases that are more prevalent at higher temperatures. Coldwater virus disease (IHN) is often a substantial problem at temperatures below 50°F. Salmonid temperature objectives in hatcheries are therefore generally within the 50-60°F range, which is much lower than the full range of Central Valley water temperatures.

VISION

The vision for Central Valley stream temperatures is to restore natural seasonal patterns of water temperature in streams, rivers, and the Delta by protecting and improving ecological processes that regulate water temperature and reducing stressors that change water temperature. Appropriate water temperatures will provide suitable fish spawning, holding, and rearing habitat conditions and contribute to the recovery of species and overall health of the Bay-Delta.

Natural temperature conditions in Central Valley streams vary along a continuum on a "longitudinal gradient" from the mountain headwaters to meandering lowland rivers, and on to the Delta. Therefore, restoration needs for stream temperatures vary for different streams and stream segments. These needs will vary by stream and stream segment, depending on existing conditions. The needs and opportunities to protect and manage Central Valley stream temperatures will depend on the conditions of the stream channel and riparian corridor, as well as the existing water supply (i.e., reservoir storage) of each tributary stream.

A primary restoration need will be to maintain relatively low water temperatures in summer and fall for anadromous fish populations in the upstream portion of each major tributary to the Delta, especially those tributaries with larger foothill reservoirs and impassable dams. In relatively wet years, with full reservoirs and high reservoir releases for downstream diversions, water temperatures below the major Central Valley reservoirs are maintained within the 50-60°F target range. However, as available water supply declines (i.e., in drier years), the ability to maintain sufficient carryover storage to sustain the release of cool water and to release sufficient flows to control downstream temperatures for salmon and steelhead rearing is substantially reduced. Sustaining adequate temperatures below reservoirs and power diversion dams is needed to provide coolwater anadromous fish habitat within the existing Central Valley multipurpose water resources management framework. Flexibility in managing stream temperatures will be an important ingredient in the successful restoration of Central Valley natural resources.

Particular attention has been given to water temperatures below Keswick Dam because this area is the only remaining spawning habitat on the Sacramento River for winter-run chinook salmon. Extremely warm water in 1976 and 1977 was likely a major cause of the decline in winter-run chinook salmon although the Red Bluff Diversion Dam likely contributed to the sustained low population of winter-run chinook throughout the period following the 1976-77 drought, even when water temperature impacts were moderated. Only very low populations of winter-run salmon have been maintained since this drought event, when Shasta Reservoir storage declined to less than 1 million acre-feet. The California Department of Fish and Game (DFG) and the Anadromous Fish Restoration Program (AFRP) suggest that Shasta Reservoir carryover storage should not drop below 1.9 million acre-feet to ensure an adequate supply of cold water for release in summer and fall. The Temperature Control Device, when operational, will provide additional flexibility in temperature control and conserving cooler reservoir waters through the summer and fall.

The State Water Resources Control Board (SWRCB) has added water temperature requirements below Keswick Dam (and in the Trinity River below Lewiston Dam) to the water rights for Shasta and Clair Engle Reservoirs. A multiagency Sacramento River Temperature Task Force is responsible for the adaptive management of Sacramento River water temperatures. It reports to SWRCB on the effects of its temperature management and the resulting winter-run chinook spawning and rearing success each year. These water management decisions are more difficult in years with limited water supply.

Whiskeytown Reservoir releases to Clear Creek, a tributary to the Sacramento River, are sufficiently cool to support salmon and steelhead. However, since 1965, insufficient streamflows and fish-passage problems have prevented this potential habitat from supporting many fish. Low-level outlets can be used for releases to Clear Creek. Efforts to manage temperatures in Clear Creek could be implemented as on the Sacramento River.

The temperature of Lake Oroville releases to the Feather River is controlled (e.g., temperature control panels) for the Feather River Hatchery and the "low-flow" channel. The objective is to maintain temperature for natural spawning and holding of spring-run salmon and steelhead. Carryover storage, sufficient to maintain low fall water temperatures, is limited during droughts. The California Department of Water Resources (DWR) is exploring operations of the Oroville-Thermalito complex to determine whether improved stream temperature controls can be achieved. As at Shasta Dam, additional means for controlling temperature are needed for these adaptive management efforts to provide optimal water temperatures within the overall water management framework. One such means would be additional storage water dedicated to temperature control in the Feather River below Lake Oroville and Thermalito Reservoir.

Yuba River water temperatures are considered well suited for salmon and steelhead below Englebright Dam (the first impassable dam), but flows and riparian vegetation have been insufficient to maintain target temperatures below the Daguerre Dam, the major water diversion dam on the lower Yuba below Englebright Dam. The Yuba County Water Agency is evaluating the temperature control potential of New Bullards Bar Reservoir (a major storage reservoir upstream of Englebright Lake on the North Fork of the Yuba River) and is working with AFRP and DFG to develop an adaptive management strategy for Yuba River flows and temperatures. Again, like at Shasta and Oroville, additional storage dedicated to water temperature and possibly the addition of temperature control devices on major storage reservoirs could improve the water temperature conditions on the lower Yuba River.

Many of the upper Sacramento River tributaries are largely nonregulated. Water temperatures on these stream and in the Sacramento River at their confluence could be improved by managing water diversions and improving riparian vegetation.

The U.S. Bureau of Reclamation (Reclamation) has recently modified the Folsom Dam temperature control panels to provide some additional temperature management potential; however, the relatively low storage capacity of Folsom Reservoir limits the ability to control temperatures at the Nimbus Hatchery and in the lower American River. Additional storage dedicated for water temperature and potential improvements to temperature controls at Nimbus Dam could improve water temperatures in the lower American River.

Temperatures in the San Joaquin River tributaries (Mokelumne, Stanislaus, Tuolumne, and Merced Rivers) are controlled by a combination of cold-water reservoir releases and streamflow management. Although initial efforts to monitor and control water temperatures on these rivers have begun, the upstream segment of each may require additional reservoir and flow management actions. Actions similar to those described above for Shasta, Oroville, New Bullards Bar, and Folsom Dams could be implemented. Long-term agreements to adaptively manage reservoirs on these San Joaquin River tributaries are needed to provide the best possible flow and temperature conditions for fish habitat while also protecting the other existing beneficial water uses.

Another primary restoration need will be to maintain cool temperatures through the spring and again in the fall in the Delta and lower rivers to provide for upstream migrating adult and downstream migrating and rearing juvenile anadromous fish. Low flows either naturally occurring or caused by water storage or diversions are the problem in these areas. Although control of water temperature is limited in the lower rivers and the Delta, restoring natural flows, riparian vegetation, connecting marsh-sloughs, and reducing warm water discharges should benefit water temperatures in small but significant ways. Shallow water habitats with adequate shade will not locally warm to intolerable levels for species dependent on them. Dead-end sloughs will maintain slightly lower water temperatures with adequate shading. Minimizing discharges of warm water such as agricultural drains into rivers and Delta will help sustain cooler temperatures further into the spring and earlier into the fall. Although water temperature changes would be small, possibly less than an degree or two, such changes are significant when overall water temperatures are stressful or approach lethal levels for some species.

Although historical stream temperatures can be used as a guideline for establishing stream temperature targets, the actual management of temperatures for each tributary or river segment will require coordination with all agencies and stakeholders. Therefore, stream temperature targets should be developed within the existing multipurpose water resource management framework for each watershed. The relative ecological value of streamflow and temperature should be estimated for each tributary stream. Streamflow and temperature should be accurately monitored and rapidly evaluated for both short-term and long-term management decisions. This basic streamflow information will then allow for flexible management of streamflows. Flexible management will allow temperatures to become a major element in the restoration of ecological functions and benefits throughout the Sacramento and San Joaquin River basins.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Water temperature in Central Valley streams is being addressed under the Central Valley Improvement Act (CVPIA) subsection 3406(b) programs being administered by the USFWS. Water temperature is also addressed in various biological opinions and recovery plans (e.g., winter-run chinook salmon) for threatened and endangered species. Water temperature is also a common criteria in water quality standards for various rivers and the Delta.

There are several important ongoing programs that attempt to improve the multipurpose water management of Central Valley streamflows and temperature conditions. The vision for stream temperature management is to complement and coordinate (where conflicts exist) these existing streamflow and temperature management programs. Several agencies are directly or indirectly responsible for stream temperature management. ERPP supports the policies and decisions of these individual agencies and could provide resources to implement stream-temperature management actions and mediate conflicts between water management goals of individual agencies.

Important stream-temperature management responsibilities and programs of agencies include:

- DWR's operation of Lake Oroville to satisfy DFG hatchery and stream temperature objectives;

- Reclamation's operation of Central Valley Project reservoirs to achieve specific temperature criteria or objectives for salmon and steelhead habitat conditions;

- Federal Energy Regulatory Commission's regulation of minimum flows below hydropower projects throughout California (e.g., Butte Creek temperatures below Centerville Diversion Dam);

- SWRCB's administration of water rights and water quality objectives (in coordination with Regional Water Quality Control Boards) necessary for beneficial uses and for fish protection below reservoirs and dams;

- DFG's responsibility to study and recommend stream temperature requirements for fish protection and propagation in streams and at hatcheries;

- USFWS's and the National Marine Fisheries Service's programs to recommend temperatures needed for mitigation of impacts from federal projects (e.g., hatcheries) and protection of endangered species (the biological opinion for winter-run chinook salmon and the AFRP each have specific temperature recommendations and requirements); and

- USGS's water resources division programs to measure streamflow and temperature to provide the information necessary for adaptive management of stream temperatures.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Water temperature is a primary ecological process closely linked with other processes, habitats, and species. Water temperatures are dependent on streamflow and riparian vegetation. Stressors including water diversions and agricultural drainage discharges affect water temperature.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for Central Valley stream temperatures is to maintain, improve, and restore water temperature regimes in order to meet life history needs of aquatic organisms.

General targets to achieve healthy Central Valley stream temperatures include:

- Maintaining water temperature below 57°F in salmon and steelhead spawning areas during spawning seasons below major dams on rivers. The ability of meeting this broad target will be influenced by in some drainages by the quantity and quality of coldwater stored behind the larger dams.

- Maintaining water temperature below 58 to 60°F in salmon and steelhead rearing areas in late winter and spring.

- Maintaining water temperature below 65°F in oversummering areas of salmon and steelhead.

- Maintaining water temperature below 70°F in migratory routes of anadromous fish in spring and fall. Meeting this target in the lower Sacramento River, lower San Joaquin River, and in the Delta may be difficult in many years as there is no practical, short-term means by which to reduce water temperatures.

Several stream temperature actions should be implemented immediately. There is general agreement that these actions will improve stream temperatures without having significant impacts on water supply or energy resources. Many of these actions have been recommended by DFG and by AFRP but have not been implemented because of limited financial resources. They include:

- Increasing coldwater releases from Whiskeytown Lake to Clear Creek to allow restoration of the habitat along this 18-mile stream segment for salmon and steelhead spawning and rearing; Whiskeytown Lake could be coordinated with the operation of Shasta Dam to minimize impacts on the water supply;

- Developing a long-term agreement with Pacific Gas and Electric Company (to provide appropriate compensation for energy losses) to monitor temperatures and provide bypass flows in the lower North Fork and South Fork segments of Battle Creek to maintain suitable temperatures for holding, spawning, and rearing habitat for spring-run and winter-run chinook salmon and steelhead;

- Restoring stream temperature monitoring capability at several U.S. Geological Survey stream gages and other strategic locations of Central Valley streams, combined with improving fish sampling and counting devices to provide a solid basis for adaptive stream temperature management decisions; and

- Increasing Feather River flows in the "low-flow" channel to a maximum of 2,500 cubic feet per second (cfs) and reducing the flows through Thermalito Forebay and Afterbay released to the Feather River. Thermalito releases can have a major effect on downstream temperatures; only water needed for irrigation diversions and peaking power generation should be diverted (energy from the Thermalito power plant would be reduced).

Because temperatures are an important habitat condition and can vary with changes in other factors, there should be a substantial commitment to continued monitoring and evaluation of the physical, chemical, and biological processes and ecological functions that are governed by stream temperature.

Many stream-temperature management actions will require a slightly longer implementation period because additional information is needed for careful planning decisions, or because detailed designs for new or modified facilities are required. Nevertheless, the necessary planning studies and engineering design work can be initiated on the following longer term actions:

- Establish coordinated stream-temperature management teams for each major stream. Coordinated teams could follow the approach used by the Sacramento River Water Temperature Task Force to help Reclamation allocate and schedule releases for Sacramento River temperature control. This cooperative management approach attempts to maximize streamflow and temperature benefits while maintaining other beneficial uses of water. The choice between carryover storage and increased releases for temperature control can best be made by this type of adaptive management team. Potential conflicts between different fish populations and other water uses can also be addressed using this strategy.

- Restore blocks of riparian habitat that are sufficiently large (>50-100 acres) to create air convection currents, which will cool adjacent river water temperatures.

- Restore and protect the stream channels and riparian corridors (i.e., pools, gravelbeds, and vegetation). Minimizing warming along the stream gradient and providing habitat features will allow fish to use cool water areas in deep pools and springs.

- Develop a comprehensive series of reservoir and stream temperature models. The models would be used to investigate the effects of possible modifications to reservoir facilities and stream channel and riparian corridor conditions. These calibrated models can form the basis for adaptive management of Central Valley streamflows and temperatures within the overall framework of multipurpose water management objectives and constraints.

To protect and improve Central Valley stream temperatures, a responsible balance must be achieved between water management for temperature controls and other beneficial uses of the available water supply.

To be implemented, these measures may require that water from willing sellers be purchased or water exchanges negotiated and alternative supplies explored. There are two general programmatic actions:

- Provide sufficient carryover storage and selective withdrawal facilities in major reservoirs. These measures would help optimize summer and fall release temperatures to allow spawning and rearing of winter-run and fall-run salmon. A target temperature of 56°F during spawning and egg incubation is appropriate because salmon eggs have increasingly high mortality rates as temperatures rise above 56°F and total mortality above 68 percent. The Shasta Reservoir temperature device is being constructed to allow warmer water to be released in spring and early summer to reserve more of the cooler water (at greater depth) for summer and fall releases. Because some carryover storage must be maintained to provide desirable temperatures downstream, specific reservoir releases for water supply may be reduced in some dry years.

- Provide sufficient summer and fall streamflows to maintain adequate holding and rearing temperatures for spring-run, fall-run, and winter-run salmon of less that 60°F and steelhead trout of less that 65°F in streams supporting these populations. This may require limiting hydropower diversions or providing higher reservoir releases than would otherwise be required for downstream diversions.

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INTRODUCTION

The Delta of today is greatly altered from its historical condition. Historically, a complex, dendritic array of channels drained extensive marsh plains. Now, theses channels have been replaced by a greatly simplified network of uniform channels.

The Delta waterways generally contain fresh water, with brief incursions of slightly brackish water into the northern and eastern Delta. This incursion is more pronounced during the spring and early summers of very dry years when the discharges from the Sacramento and San Joaquin rivers are low. This differs from the natural pattern in which brackish water intrusion naturally occurred in late summer and early fall.

Beginning in the mid 1800s, the Delta has been subject to the effects of alteration of the natural seasonal patterns of river discharge, Delta morphology, and tidal prism. These factors interact to determine water movement patterns and salinity distribution in the Delta. Salinity levels in Delta waters is primarily a result of tidal prism and stage, and net Delta outflow. It is also influenced by prevailing wind direction and velocity. Daily tidal cycles result in flows in the lower San Joaquin River of up to 300,000 to 400,000 cfs, and the spring-neap cycle alters water surface elevations and salinity levels on a monthly basis.

Other factors that now contribute to alteration or moderation of historic flow patterns in Delta waterways and channels include operation of the CVP/SWP pumping plants in the south Delta, the Suisun Marsh Salinity Control Structure, the Delta Cross Channel (DCC), and a temporary flow barrier on the San Joaquin River at the head of Old River. The DCC and Old River Barrier affect flow rates, direction, and water surface elevations. At times, these factors contribute to the creation of unnatural flow patterns which is particularly evident in the channels of the southern and central Delta.

Hydraulic processes are an extremely important aspect of the Bay-Delta system and refers to the seasonal and daily direction and velocity of flows in Bay-Delta channels. The direction and velocity of flow and their distribution in time and location are important factors in habitat preferences of Bay-Delta organisms, erosion and sedimentation processes, migratory cues for organisms, and many other ecological processes and functions in the Bay-Delta. Major factors that affect hydraulics of Bay-Delta channels include streamflow, sediment composition, and channel configuration.

Flow conditions in Delta channels affect foodweb production, transport of organisms through the Delta, and vulnerability to south Delta pumping plant diversions. The Bay-Delta estuary provides important fish spawning, rearing, and migrating habitats. The Bay-Delta also serves as an important link in nutrient cycling and provides for high levels of primary (plant) productivity that supplies the aquatic foodweb.

RESOURCE DESCRIPTION

Nonimpeded tidal action into tidal wetlands affects sediment and nutrient supplies into those wetlands and complements natural marsh successional processes. Tidal action associated with flows out of tidal wetlands transports nutrients and organic carbon into aquatic habitats of the Bay-Delta.

Hydraulic patterns in the Delta are important to the survival of delta smelt, longfin smelt, striped bass, chinook salmon, and other fish dependent on the Sacramento-San Joaquin Delta. Unfavorable hydraulic conditions, such as net flow moving south to Delta export facilities instead of moving west toward Suisun Bay, reduce fish survival.

Improved hydraulic patterns will increase residence times of Delta water; provide more natural downstream flows; and improve rearing and spawning habitat, nutrient cycling, and foodweb integrity.

Delta hydraulics are determined by a combination of flow parameters including Delta inflow, Delta diversions, tidal flows, and facility operations (e.g., operation of the DCC gates). Cross-Delta water flow to the south Delta pumping plants reduces residence time of water in the Delta and alters flow direction and magnitude.

Unfavorable hydraulic conditions decrease juvenile chinook salmon survival as they migrate from the Sacramento River through the Delta. With a high rate of north-to-south flow from the Sacramento River through the DCC and Georgiana Slough into the central Delta, young salmon may become lost or delayed within the Delta, or may become more susceptible to being drawn to the south Delta pumping plants.

Favorable hydraulic conditions are important for chinook salmon because the Delta is a migration corridor and also provides rearing habitat. Juvenile chinook salmon rearing in the Delta are exposed to adverse hydraulic conditions for approximately 1-3 months until they are ready to migrate to the ocean.

Other species, including striped bass and delta smelt, are also subject to being drawn south across the Delta to the pumping plants. Because the water has a short residence time, the food supply is generally poor for those fish drawn into or residing in the central and southern Delta.

VISION

The vision for hydraulic processes in the Sacramento-San Joaquin Delta is to restore channel hydraulics to conditions more like those that occurred during the mid-1950s by maintaining hydraulic conditions to provide migratory cues for aquatic species; transport flows for eggs, larvae, and juvenile fish; and transport of sediments and nutrients.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

The objective of one current program, the Temporary Barriers Program in the south Delta, is to improve the quantity and quality of irrigation water to agricultural users in the south Delta. A secondary objective is to provide a physical barrier in spring at the head of Old River at its junction with the San Joaquin River to reroute outmigrating San Joaquin fall-run chinook salmon downstream and away from the export facilities. In fall, a partial rock barrier modifies channel hydraulics to reduce the risk of dissolved oxygen blocks near Stockton and to ensure that a greater percentage of attraction water from natal streams reaches the Central and West Delta Ecological Unit.

The DCC gates are required to be closed under the terms of the National Marine Fisheries Service's biological opinion on winter-run chinook salmon and the 1995 Water Quality Control Plan to reduce impacts on salmon migrating down the Sacramento River. The gates can be closed at the request of the California Department of Fish and Game for half of November, December, and January. The DCC gates are then closed from February 1 through May 15.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Bay-Delta hydraulics are closely linked to the health of aquatic habitats in the Bay-Delta and the aquatic resources that depend on these health habitats. These include:

- Tidal perennial aquatic habitat,
- Delta sloughs, and
- Midchannel islands and shoals.

Species and species groups that are dependent on healthy hydraulic conditions in the Bay-Delta include:

- Delta smelt,
- Longfin smelt,
- Striped bass,
- Chinook salmon, and
- Many other estuarine and resident aquatic species.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for Bay-Delta hydraulics is to establish and maintain a hydraulic regime in the Bay-Delta to provide migratory cues, create and maintain habitat, and facilitate species distribution and transport.

The general target for restoring and maintaining healthy Bay-Delta hydraulics is to focus on restoring hydraulic patterns typical of those exhibited when the ecosystem was functioning in a healthy state (e.g., 1960s).

The general approach to attain the target include the following:

- The effects of water exports and lower riverflows can be reduced by altering Delta channel configurations to improve system hydraulics. The two ecological units that have the greatest need for improved hydraulics are the South Delta and Central and West Delta Ecological Units.
- The greatest opportunities to restore hydraulic processes to reference levels that occurred when the estuary was healthier are linked to the water and storage alternatives. The potential for restoration is limited by a water storage and transport component that has its only export facilities located in the South Delta Ecological Unit. Under that condition, increased storage upstream or downstream of the Delta could reduce exports in portions of some months and improve hydraulics during those times. There is a greater potential to restore hydraulic transport patterns with a water storage and transport component that allows for exports to occur from outside of the internal Delta during major portions of the year. Other more limited opportunities exist that are associated with storing water in the Delta, using physical barriers in strategic locations in the Delta, broadening specific sloughs to increase their flow-bearing capacity while reducing water velocities, and restoring large acreages of tidal wetlands and tidal channels to increase the tidal volume of the estuary.

INTRODUCTION

The aquatic foodweb of the Bay-Delta ecosystem is the web of organisms through which energy transfers up through the different trophic levels from the lower level that includes the plants to the highest level that includes the fish, water birds, and marine mammals. Each level in the web receives energy from the lower levels. The lower or primary producer level gets energy from photosynthesis or basic forms of dissolved organic compounds in the water. The second level is generally the primary consumers or herbivores (e.g., bacteria and algae-eating zooplankton) that feed on the plants or plant products. Secondary and tertiary consumers are further up the foodweb.

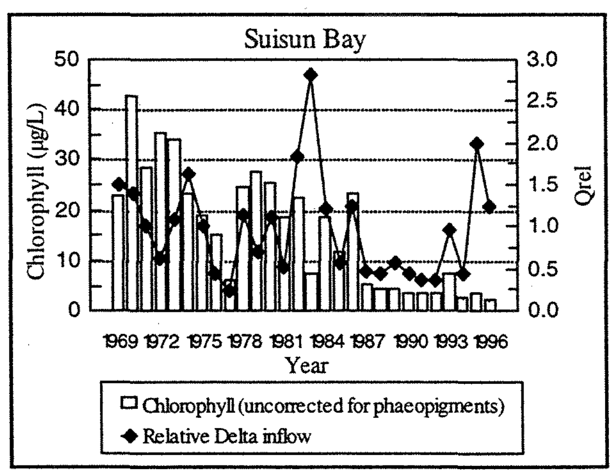
Total productivity of the Bay-Delta estuary is dependent primarily on the amount of plant biomass produced and the efficiency in which the energy is transferred up through the higher levels of the web. The Bay-Delta aquatic foodweb is derived from energy created by many kinds of plants, some of which are grown in the Bay-Delta waters and adjacent riparian and wetland habitat, while others are from upstream or land production.

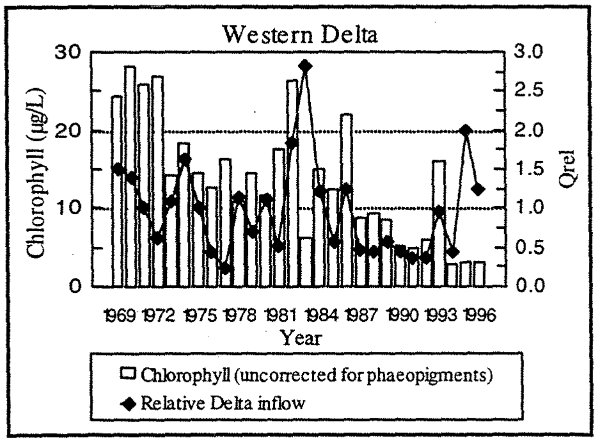
RESOURCE DESCRIPTION

Plant contributions to the estuary foodweb consist mostly of benthic algae and phytoplankton produced in the estuary and its watershed. "Benthic" foodweb organisms are bottom dwelling, whereas plankton spend most of their time drifting in the water column. Vascular-plant debris contributed from terrestrial or wetland communities adjacent to the system also contribute to the foodweb. Algae are generally small (diameter <0.1 millimeters [mm]), easily transported, and highly nutritious; whereas most vascular-plant debris begins as coarse particulate organic matter that must be colonized and partially decomposed by bacteria before being usable by invertebrates and fish.

The Bay-Delta foodweb has undergone many changes since the 1960s. Most notably, algal abundance (as measured by chlorophyll concentrations in waters of the estuary) has declined in important fish nursery areas of Suisun Bay and the western Delta. Lowered algal abundance in Suisun Bay coincides with very low Delta outflow during drier years, particularly in the drought years, such as 1977 and 1987-1992, and with very wet years, such as 1983 and 1995. However, many species of zooplankton underwent their largest declines between 1970 and 1980, well in advance of the 1987-1992 drought (Obreski et al. 1992). Chlorophyll levels greater than 20 micrograms-per-liter (μg/l) represent in Suisun Bay only twice since 1986.

Over the past three decades, chlorophyll concentrations upstream in the western Delta have been similar to those in Suisun Bay. As in Suisun Bay, concentrations are lower in dry years and very

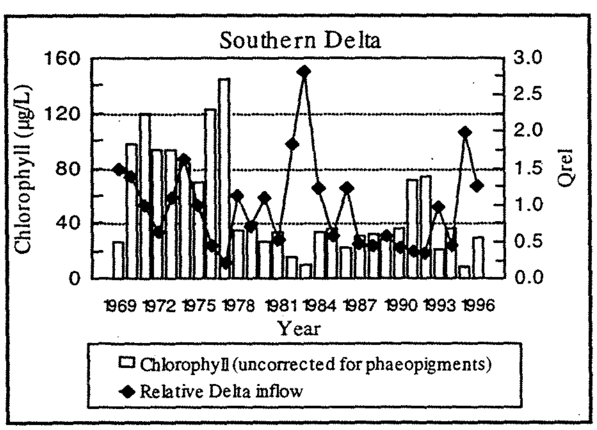




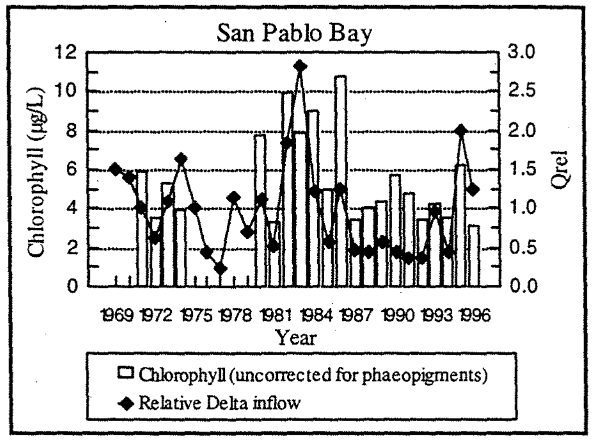
wet years. productive water. Such levels have been achieved in only two years since 1986.

A pattern of very low chlorophyll levels in Suisun Bay and the western Delta beginning in 1987 has caused concern among many scientists. These low levels may be the result of high densities of Asian clams (*Potamocorbula amurensis*) which colonized the Bay after being accidentally introduced from the ballast waters of ships. Large numbers of the clams colonized this area of the estuary during the drought period from 1987 to 1992.

Some of the plant production appearing in the Delta and Suisun Bay is washed down from south Delta channels and the San Joaquin River. Chlorophyll levels in these channels reached an



average of more than 100 $\mu g/l$ in spring and summer of some years in the early 1970s. In the

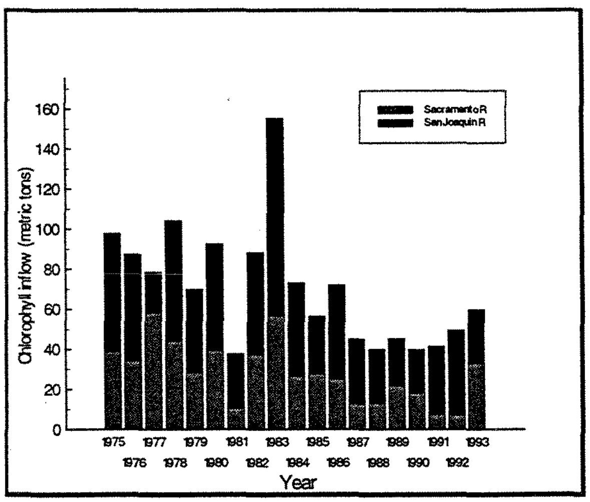


past two decades, productivity in these channels, although remaining relatively high, has declined. Levels in 1993, 1995, and 1996 were low, possibly because of high flows (as in 1982, 1983, and 1986); however, lower than expected levels in recent dry years are a concern.

In wet years, some algae and other plant material in Suisun Bay and the Delta are transported tidally downstream into the wider expanses of San Pablo Bay and other portions of San Francisco Bay. Spring and summer chlorophyll levels in San Pablo Bay are generally low compared with those in Suisun Bay and the Delta. Peak concentrations in the past three decades in San Pablo Bay occurred in wet years (1980, 1982, 1983, 1984, 1986, and 1995).

Aquatic invertebrate population trends have varied significantly over the past three decades. Species that once dominated the aquatic invertebrate community have become relatively scarce such as *Eurytemora* and *Neomysis*, while some others have increased in relative abundance. Many native species have become less abundant or more narrowly distributed, while dozens of new non-native species have become well established and widely dispersed. Overall, the abundance of invertebrate plankton has declined, while most notably populations of Asian clams, have increased. This transition has been most evident in Suisun Bay and other traditionally important fish-rearing areas such as the western Delta and Montezuma Slough in Suisun Marsh. Also in these areas, populations of rotifers, copepods, and other relatively small species have declined substantially since monitoring began in the 1960s. This pattern is perhaps most dramatic for the mysid shrimp, which has declined to less than one-tenth of its former abundance, particularly since 1986. The continued decline from 1993 to 1995, despite the return of higher flows, is of particular concern. These declines in zooplankton abundance have roughly coincided with the decline in algae, one of the main food sources for the zooplankton.

The deterioration of the zooplankton community and its algal food supply in key habitat areas of the Bay-Delta is a serious problem because striped bass, delta smelt, chinook salmon, and other species that use Suisun Bay and the Delta as a nursery area feed almost exclusively on zooplankton during early life. Limited research indicates that survival and growth of fish larvae may improve with increased concentration of zooplankton. Declines in the production of juveniles of these fish species appear to coincide with the declines in algae and zooplankton. Modifying the Bay-Delta ecosystem in ways that will lead to increased algae and zooplankton abundance, such as increasing the residence time of water in the Delta, may be critical to restoring Bay-Delta fish populations and improving the health of its ecosystem.



May-October Chlorophyll Inflow to Delta, 1975-1993

Much of the plant biomass and other forms of fine particulate organic matter consumed by zooplankton in the Bay-Delta is transported from the Sacramento and San Joaquin Rivers and accumulates in the western Delta and Suisun Bay. Some organic matter also comes from the lower mainstem rivers and from side channels, side sloughs, and floodplain lakes. Large amounts of organic matter and associated bacterial biomass enter the rivers, Bay, and Delta as crop residue, leaf litter, dead tule stems, and other organic debris from riparian corridors, floodplains, or other areas subject to periodic flooding by tides and high flows. Historically, considerable organic material entered the rivers and Bay-Delta from sewage and food-processing plants. These point source loadings have since been reduced as part of an overall effort to improve water quality.

The San Joaquin River contributes a disproportionately high percentage of the food resources supplied to the Delta. The river's chlorophyll levels are among the highest recorded for temperate rivers anywhere in the world. San Joaquin River water has a relatively long hydraulic residence time and high phosphorus and nitrogen levels. Under these circumstances, algae have an abundant supply of nutrients and enough time to process them before being swept downstream into the Delta. The Sacramento River, by contrast, has relatively low nutrient levels throughout most of its length and a comparatively short residence time and, therefore, low productivity.

These differences between the San Joaquin and Sacramento Rivers are partly a result of natural differences in regional soils and hydrologic conditions, but are also a function of how the two rivers have been engineered and operated to meet water supply needs. The San Joaquin River is fertile and sluggish from May to October because it consists primarily of agricultural return flows. In contrast, the Sacramento River consists primarily of reservoir releases that are relatively nutrient poor. Although the San Joaquin River accounts for only 17% of Delta water inflow from May through October, it contributes 60% of the plant material flowing into the Delta.

From May through October, the amount of plant material flowing out of the Delta exceeds the amount transported in from the rivers by an average of 44%. This difference results from production of algae within the Delta. Most of the plant material transported to or produced within the Delta flows out of the Delta, either through the main channel connecting the Delta with Suisun Bay or by way of the project pumps in the southern Delta. Of the total outflow of water and plant material from the Delta (i.e., project exports plus "net Delta outflow" to Suisun Bay), on average two-thirds goes to Suisun Bay and one-third is exported by the pumps.

The proportion of the organic material in the Delta that reaches Suisun Bay varies considerably from year to year and depends, in part, on prevailing flow conditions. At higher flows, much of the organic material brought in by the rivers will travel to Suisun Bay or farther to San Pablo Bay or central San Francisco Bay. At low flows, a greater proportion remains in the Delta or is exported from the south Delta pumping plants.

In addition to serving as a critical habitat area for food production and accumulation, Suisun Bay is an area of intense food consumption. Before the prolonged drought that began in the mid-1980s, high densities of copepods, young mysid shrimp, and other planktonic grazers usually accompanied relatively high chlorophyll levels in Suisun Bay. Dozens of species of filter-feeding clams and other benthic grazers joined in the intense food consumption. Since the drought ended in 1993, however, chlorophyll concentrations have remained low in Suisun Bay.

The Asian clam is likely responsible for this lack of plankton recovery. This non-native marine bivalve was first detected in Carquinez Strait in 1986. Since then, it has become very abundant throughout San Pablo Bay and Suisun Bay and, in dry years, extends upstream into the western Delta. It is estimated that the clam can effectively filter the entire water column within 24 hours. Therefore, some scientists believe that these clams are effectively removing algae and other fine organic materials from the water column of Suisun Bay almost as fast as the Delta can supply it. The Asian clam is, therefore, considered an important "stressor" that will likely hamper efforts to restore the Bay-Delta foodweb; however, clam densities and the extent of their upstream distribution in the estuary have declined since 1993 with the onset of higher freshwater winter and spring inflows associated with wet years in 1993, 1995, and 1996.

The decline of plankton populations and chlorophyll concentration in the Bay-Delta may be a result, at least in part, of the effects of heavy metals, herbicides, pesticides, and other toxic substances. Low concentrations of these substances in the water column may act individually or in combination to reduce productivity of plant and animal plankton. Laboratory tests of Delta water on sensitive organisms indicate periodic toxicity of Delta water.

VISION

The vision for the Bay-Delta aquatic foodweb is to restore primary and secondary production to levels comparable to those during the 1960s and early 1970s. Restoring the Bay-Delta foodweb would require enhancing productivity and reducing loss of productivity as a result of water exports from the system, particularly in drier years.

Although zooplankton abundance has declined in suisun Bay, herbivore productity (i.e., productivity of Potamocorbula(in suisun Bay is still very high. Thus, in Suisun Bay, energy from primary production flows mainly to the benthos instead of to zooplankton in the water column. The vision is also in evaluate means by which to restore primary and secondary production and increasing zooplankton biomass.

There are several means to enhance Bay-Delta productivity. A by which to maintain or increase productivity is to reduce the loss of nutrients, plants, and animal plankton to water diversions. Additional improvements can be gained by increasing shallow-water habitat and tidal wetlands in the Bay and Delta, which would result in more plant production. Increasing the acreage of floodplain lakes, sloughs, and other backwaters in the Sacramento and San Joaquin Rivers will further increase organic matter inputs to the Delta. Reducing the amount of toxic substances entering the system will reduce loss of primary and secondary production. Other means of increasing productivity of the aquatic foodweb include opening leveed lands to tidal or seasonal floodflows; increasing the array of sloughs in the Delta; protecting and restoring shallows, shoals, and channel islands in the Delta; and providing for a more natural floodplain and meander belt along the rivers.

Restoring tidal action to leveed lands in San Pablo Bay, Suisun Marsh, and the Delta enhances productivity by allowing Bay-Delta waters to capture their plant production. The Yolo and Sutter bypasses offer potential opportunities to produce more permanent slough, riparian, and wetland habitats in the Sacramento River floodplain. Setback levees or improved riparian and shallow-water habitat along leveed reaches of the rivers and Delta offer additional opportunities to increase productivity of the Bay and Delta. These actions will promote aquatic and riparian plant production, which should improve the plant material base of the foodweb. With greater plant material available, the productivity of consumers like zooplankton will be greater, which in turn will increase the productivity of many important fish and wildlife species in the Bay-Delta.

There are several ways to ensure that increased plant material transported to or produced in the Delta is transported to Suisun Bay. Changes in the timing and magnitude of flows through the Delta and exports from south Delta pumping plants may increase transport of organic materials to the Bay from the Delta. Spring flow pulses in drier years from the rivers will enhance productivity in the rivers, Bay, and Delta and ensure that a greater amount of this productivity is transported through the Delta to the Bay. More of the organic material transported to or produced within the Delta would be retained in the Delta or transported to the Bay if the south Delta export pumps were relocated to the northern Delta.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore the productivity of the Bay-Delta foodweb would involve the cooperation and support from established programs underway to restore habitat and fish populations in the Bay-Delta including the following:

- The Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes calls for improving flows, reducing diversions, and increasing habitat.
- The Salt Marsh Ecosystem Recovery Plan calls for improving a wetland habitat in the Bay.
- The Recovery Plan for Winter Run Chinook Salmon (NMFS) includes recommendations for habitat and foodweb restoration in the Bay-Delta and Sacramento River.
- The Recovery Plan for the Salt Marsh Harvest Mouse and California Clapper Rail includes provisions for protection and restoration of wetland habitats in the Bay.
- The Central Valley Project Improvement Act (PL 102-575) and its associated Anadromous Fish Restoration Plan includes provisions to reduce losses of organisms into water diversions, to restore aquatic habitat, to improve water quality, to improve freshwater flows, and to restore wetland and riparian habitats in the rivers and Bay-Delta.
- The Steelhead Trout, and Anadromous Fisheries Program Act of 1988 includes elements to improve freshwater flows and riparian habitats in the Sacramento and San Joaquin Rivers and their tributaries.
- The Delta Wildlife Habitat Protection and Restoration Plan include protection and improvements to riparian and wetland habitats of the Bay-Delta.

- Central Valley Habitat Joint Venture includes restoration of riparian and wetlands of the rivers, Delta, and Suisun Marsh.

- US Army Corps of Engineers Yolo Basin Wetlands Creation and Restoration Project will increase wetland acreage in the Yolo Bypass.

- California Senate Concurrent Resolution 28 has set a goal of doubling wetland acreage by the year 2000.

- San Francisco Estuary Project planning for wetland protection and restoration, and water quality protection and improvement.

- San Joaquin River Management Plan is a plan to restore riparian and wetland habitats and improve water quality in the San Joaquin River and its tributaries.

- SWRCB and RWQCB efforts to restore wetlands and improve water quality of the rivers and Bay-Delta.

- Suisun Resource Conservation District is developing wetlands restoration and management plans.

- The San Francisco Bay Joint Venture is a public/private partnership working to protect, restore, enhance and increase wetlands of all types throughout the San Francisco Bay region to benefit fish and wildlife using a non-regulatory approach.

- Riparian Habitat Joint Venture will restore riparian habitats.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Improvement of the aquatic foodweb of the Bay-Delta is integrally linked with wetland and riparian habitat restoration, water quality (contaminants) improvement, and Central Valley streamflow improvements.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for Bay-Delta aquatic foodweb is to maintain, improve, or restore the amount of basic nutrients available to estuarine and riverine systems in order to provide a sustainable level of foodweb productivity.

The general targets for a healthy Bay-Delta aquatic foodweb include:

- Restore chlorophyll "a" abundance in San Pablo and Suisun Bays, and in the Delta to levels that occurred in the 1960's and early 1970's.

- Restore abundance of important zooplankton species in San Pablo and Suisun Bays, and in the Delta to levels that occurred in the 1960's and early 1970's.

General programmatic actions to contribute to attaining targets include:

- Increase the residence time of water in the Delta.

- Restore tidal action to diked wetlands.
- Reduce concentrations and loadings of trace metals, herbicides, and other toxic substances in sediments and waters of the Central Valley.

- Reduce losses to diversions by modifying the structure and operation of Delta conveyance and pumping facilities.

- Increasing the amount and diversity of organic matter input from the Bay-Delta watershed by restoring aquatic, riparian, and wetland habitats.

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UPPER WATERSHED PROCESSES - FIRE AND EROSION

INTRODUCTION

Upper watersheds comprise geological areas and ecosystem elements of Central Valley rivers above the valley floor. The upper watershed designation also applies to creek and rivers that feed into North, Central, and South San Francisco Bay (including San Pablo Bay, Honker Bay, and Suisun Marsh). Much of the upper watersheds are outside the primary study area for CALFED. However, they are included here because their health directly affects the health of the Bay-Delta ecosystem.

Major factors that affect upper watershed health and function are forest "fuel" levels, fire suppression, wildfire, road building and maintenance, water diversions, livestock grazing, timber harvest, tree diseases, and forest management practices.

Water supply and water quality in the Central Valley require healthy watershed processes in the upper portions of the tributary watersheds. Land and resource management in the upper portions of tributary watersheds have substantially modified watershed processes. This has affected the reliability of high-quality water inflows to the Sacramento-San Joaquin Delta and San Francisco Bay. Management activities have also affected the available capacity of reservoirs that store water for water supply and provide flood control to downstream residents.

RESOURCE DESCRIPTION

FIRE

Prehistorically, fire was a principal mechanism by which the nutrients contained in forest material were recycled. With fire frequency reduced since the late 1800s, the rate of nutrient release has been reduced, which has influenced the forest and watershed health. The Native American practice of setting fires to enhance their environment has stopped. Fire suppression policies and large-scale livestock grazing have been introduced (Vankat 1977, Kilgore and Taylor 1979, Swetnam et al. 1992). In response, rates of materials decomposition have dramatically declined and fuels have accumulated throughout most upper-watershed wildlands.

Because wildfires are less frequent, they now burn larger areas with higher intensity and with greater environmental damage than occurred during the presettlement period (McKelvey et al. 1996). Wildfires can have devastating effects on watershed health that, in turn, affects the quantity, timing, and quality of inflows to the Delta and San Francisco Bay from the upper watersheds. Catastrophic wildfire can produce more intensive and extensive changes in watershed conditions than any other form of disturbance (Kattelmann 1996).

Over the past century, fire suppression and logging of large conifers have resulted in forests dominated by dense stands of tree species that are relatively small, shade tolerant, and fire sensitive, such as white firs and incense-cedars (Parsons and DeBendeetti 1979). Consequently, there has been a large increase in the volume and continuity of live and dead wood fuels near the forest floor. These fuels provide a "ladder" that connects surface fuels with the forest canopy (McKelvey et al. 1996). Risks of large, severe fires have increased accordingly. Such changes have been greatest in the lower and middle elevations of the Sierra Nevada, which is also where human development has been most rapid. With the increase in hazardous fuel conditions, human populations and property potentially endangered by fire have also increased. On a regional scale, Sierran forest ecosystems are believed to be outside the range of variability that was present in the historical ecosystem regarding fire frequency and severity, forest structure, and landscape mosaic (distribution of vegetation patches) (Skinner and Chang 1996).

Excessively dense conifer stands are widespread in the Sierra Nevada. These stands have dense understories that provide the horizontal and vertical continuity of fuels that fires need to move from the ground surface to the forest canopy. Excessive competition for water and sunlight in dense stands often weakens or kills trees, resulting in increased fuel loads, potential fire severity, and the rate of spread (Weatherspoon 1996). Present fuel conditions in much of the Sierra Nevada increase the potential for large, severe fires (Sapsis et al. 1996).

Timber harvesting substantially increases fire hazards unless postharvest slash treatments (e.g, piling and burning) are implemented (Stephens 1995, Weatherspoon 1996, Van Wagtendonk 1996, Elliott-Fisk et al. 1996). Forest-practice regulations, which apply on all private timberland in California, require only minimal slash treatments (e.g., lopping branches and tops) and only in a highly limited area (within 50-100 feet of publicly accessible roads and 100-200 feet of structures maintained for human habitation) (14 CCR 917.2).

Catastrophic fire is detrimental to watershed function and water quality. By killing vegetation, burning the organic matter in litter and soil, and forming impervious soil layers, severe fires accelerate runoff from the watershed. More water is discharged over a shorter period of time, peak flows are greater (contributing to increased flood hazards), and summer and fall streamflows are lower than those in less disturbed watersheds. Bare soils and increased runoff cause greater detachment and transport of soil particles. With reduced infiltration, mudslides become more prevalent. Sediment carried to streams increases markedly, particularly where riparian vegetation is burned (Kattelmann 1996).

In addition to the direct effects of catastrophic fires, ground disturbance related to fire suppression and postfire activities (e.g., salvage logging) adversely affects water quality. Although total annual water yield from a watershed may increase for several years following a fire, the value of the increased yield is limited because it occurs during peak flows, does not contribute to maintaining summer base flows, carries sterile material, and increases turbidity and erosion.

EROSION

Excessive erosion accelerates the filling of downstream water storage reservoirs and reduces available storage water supply. Roads are probably the most significant cause of accelerated erosion in western montane forests (Kattelmann 1996). Roads reduce rainfall infiltration, oversteepen adjacent cut-and-fill slopes, and, by intercepting subsurface flows, divert runoff across compact surfaces. Stream crossings are particularly important sources of sediment because of their direct disturbance to the channel. The failure of an individual culvert, for example, can cause gullies and landslides, resulting in hundreds of tons of sediment entering streams and storage reservoirs (Weaver and Hagans 1994). Landslides and surface erosion can often be traced to haphazard road design, location, and construction. Carefully planned road systems disturb less ground and produce less sediment than poorly planned systems.

Road instability is often increased by inadequate maintenance. Funding for maintenance of forest roads in the State is inadequate and continues to decline. In addition to removing unneeded roads or closing them seasonally, reshaping roadcuts, pulling back side-cast material, "ripping" compacted surfaces, and removing stream crossings can be effective means of rehabilitating watersheds (Kattelmann 1996).

Although soil disturbance associated with felling trees and skidding logs expose forest soils to rainfall, which causes some soil compaction, timber harvesting has less of an effect on soil erosion than road construction (Kattelmann 1996). Clearcut areas are susceptible to erosion until vegetative ground cover becomes reestablished. After harvest, the ability of the remaining tree roots to inhibit erosion gradually declines until new trees become well established. Using tractor skidders on highly erodible or unstable areas can lead to accelerated erosion or landslides. Timber harvesting and using heavy equipment adjacent to streams increases streamside erosion. Best management practices implemented by the U.S. Forest Service (USFS) on national forest lands and required on private forest lands by the California Forest Practice Rules limit the extent of clearcuts and the use of heavy equipment on erodible or unstable lands.

Timber harvesting affects peak flows by reducing transpiration (i.e., the amount of water used within a specific period by plants to build tissue) and accelerating snowmelt by exposing snow-covered areas to the sun. Excessive vegetation removal can increase flooding, particularly during small and moderate storms and in small basins (Kattelmann 1996); however, increased thinning and selective harvesting has the potential to increase total water yield by reducing transpiration.

Like road construction and timber harvest, past grazing practices have left a legacy of watershed degradation in California. Livestock grazing has probably affected more land in the Sierra Nevada than any other management activity (Menke et al. 1996). Although livestock density on forest lands has generally declined since the late 1800s, grazing continues to affect watershed health and function.

The hydrologic effects of grazing are primarily related to livestock behavior and management. Loss of streamside vegetation from grazing promotes soil compaction and erosion. Trampling of streambanks causes erosion and sedimentation in many montane meadow streams. Removal of riparian vegetation by livestock in headwater valleys of the North Fork Feather River, for example, has led to rapid channel widening and massive sediment loads (Kattelmann 1996). Impacts of grazing on watersheds can be substantially reduced by removing livestock before damage becomes too great.

VISION

The vision for upper watershed health and function is to reduce the level of stressors including wildfire, erosion, and managing timber harvest, livestock grazing, and land use management practices that effect watershed health and the ability to contribute to the health of the Bay-Delta ecosystem.

Current land uses in the upper watersheds make it infeasible to return to the prehistoric fire regime, where fires occurred every 8-26 years depending on vegetation type and climate (McKelvey et al. 1996). Not only are structures, infrastructure, and managed forests at too great a risk of fire damage to permit burning at the pre-European average rate of at least 1 million acres annually, but regulatory constraints and the social costs of fire and its effects (e.g., low air quality) prohibit burning at pre-European scales. Although fire will remain an essential element of these wildland ecosystems, it must be controlled and used in conjunction with other techniques to reduce fuel loads to levels consistent with maintaining watershed and forest health.

Prescribed fire is an effective tool for managing forest fuels (McKelvey et al. 1996). It includes prescribed ignited fires (fires intentionally set to burn a planned area at a planned intensity) and prescribed natural fires. Prescribed natural fires are those resulting from unplanned ignitions (caused by lightning or humans) but for which plans have been adopted that specify conditions and areas under which such fires will be allowed to burn. Prescribed natural-fire planning represents an important opportunity for wildfires to help meet management objectives, rather than be in conflict with them. Mechanical fuel-management techniques (e.g., thinning) can also reduce fire hazard (Elliott-Fisk et al. 1996).

From a practical perspective, perhaps the most important requirement for successful fuel management programs is a viable market for small trees and other biomass materials removed from wildlands. Products made from these materials include pulp chips, panel products (e.g., particle board), biomass energy fuel (e.g., for production of electricity), ethanol, and lumber. A major limitation on the marketability of biomass materials is their high handling costs. Recent innovations in logging equipment could substantially increase the feasibility of marketing such materials, which, in turn, would enable more extensive fuel treatments.

Unless resource commitments are made to implement fuel management on an unprecedented scale, catastrophic wildfires will have increasingly detrimental environmental and socioeconomic consequences, among the most important of which are impaired watershed functions and nonsustainable yields of high-quality water.

Except for spur roads that are needed to access local areas, the forest road systems that provide access to the montane regions of California are largely complete. Although thousands of miles of existing roads are obsolete or in disrepair, they continue to supply large volumes of sediment to streams (Kattelmann 1996). Substituting modern cable yarding systems for tractor log skidding could provide opportunities to replace many streamside roads with midslope or ridgetop roads to reduce sedimentation. Road realignment and installation of adequate drainage in poorly designed and drained segments could reduce erosion and sedimentation throughout the upper watersheds.

Effective implementation of best management practices for silviculture (growing forests) are likely to minimize the adverse effects of timber harvesting on watershed health and function. For example, compliance with streamside zone protection measures, restrictions on use of tractors on highly erodible and unstable areas, and limits on the size and density of clearcuts will minimize accelerated sedimentation associated with logging. Expanded thinning of dense forest stands could increase water yields.

Increased management of livestock herds to avoid depleting residual vegetation, removing riparian vegetation, and trampling streambanks will reduce the effect of grazing on stream sedimentation.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

FUEL MANAGEMENT

Recognition of the critical need to increase wildland fuel management has increased substantially in recent years. Several land management and wildfire suppression agencies have implemented or expanded programs to increase the application of fuel treatments. ERPP's goals will be advanced by coordinating with and supporting the following programs.

- California Department of Forestry and Fire Protection's Vegetation Management Program. The Vegetation Management Program (VMP) was initiated in 1981 to reduce wildfire damage and enhance resource values by reducing wildland fuel hazards. For several years, VMP focused primarily on prescribed burning of private rangelands. Following a series of catastrophic wildfires in southern California in fall of 1993, the California Department of Forestry and Fire Protection (CDF) convened the VMP Working Group to review the program's purpose and performance. As a result of that review, VMP's focus has expanded to encompass all major ecosystems in the State and a wide range of fuel management techniques. Its focus has shifted to reducing hazards at the urban interface, where most assets are at risk. In addition, the acreage targeted for annual treatment is substantially greater than the average acreage that has been treated in the past. CDF is preparing a program environmental impact report to facilitate environmental compliance for a wide variety of fuel treatment projects.

- California Department of Forestry and Fire Protection's Prefire Management Initiative. As part of the California Fire Plan, CDF is implementing a prefire management initiative to conduct prefire planning at the ranger-unit (i.e., county or multicounty) level throughout the portions of the State for which CDF has fire suppression responsibility (California Board of Forestry 1996). Three ranger units (Nevada-Yuba-Placer, Tuolumne-Calaveras, and Riverside) initiated this planning process in 1996; the 19 remaining ranger units and six contract counties are expected to initiate it in 1997. The process is scheduled to be completed in 1999.

  The prefire planning process will be based on developing geographic information system (GIS) maps depicting assets at risk, levels of fire suppression service, and fire weather severity. Community-level public meetings will be held to review the maps for accuracy and to solicit input regarding acceptable levels of service by area. Ranger unit staff will validate high-risk locations, which will provide the focus for developing prefire management prescriptions, and prioritize projects based on cost-effectiveness. Additional stakeholder meetings will then be held to review project priorities.

- California State Water Resources Control Board's Delta Tributary Watershed Program. As part of the California Safe, Clean, Reliable Water Supply Act (Proposition 204), the State Water Resources Control Board (SWRCB) is administering the Delta Tributary Watershed Program. This is a $15 million grant program to enable rehabilitation projects in watersheds tributary to the Sacramento-San Joaquin Delta or the Trinity River. Eligible projects will reduce contamination of drinking water, increase water yield or watershed retention capability, enhance fish habitat, control sedimentation, or improve overall forest health.

- U.S. Department of Agriculture Forest Service's Forest Health Initiative. A 1995 report recommended that the U.S. Forest Service shift from its traditional focus on fire suppression and control to comprehensive fire management, taking into consideration the essential role of fire in forest ecosystems (U.S. Department of Agriculture 1995). The agency subsequently announced a commitment to improve forest health throughout the national forests in the western United States, including expanded application of fuel management in densely stocked stands with excessive fuel loads (U.S. Department of the Interior and U.S. Department of Agriculture 1995). Underlying this initiative is the goal of maximizing the amount of national forest land periodically receiving fuel management treatment.

- The Quincy Library Group's Community Stability Proposal. The Quincy Library Group (QLG) is a coalition of diverse stakeholders from Lassen, Plumas, and Sierra Counties who have organized to obtain consensus on forest management policies to promote forest health, ecological integrity, adequate timber supply, and local economic stability. Because most of the land in these counties is in national forests, QLG is focused primarily on strategies for managing federal forest land. Portions of the budgets of the Lassen, Plumas, and Tahoe National Forests have been allocated for projects developed by QLG. QLG is the most highly developed example of local consensus-building to influence national forest management policies and programs including those for watershed restoration and fuel hazard reduction.

ROAD-RELATED WATERSHED HAZARDS

- Watershed Assessments for Programmatic Environmental Compliance Documents. Many private timberland owners are conducting watershed assessments as part of their preparation of environmental compliance documents to meet federal or State regulatory requirements. The federal Endangered Species Act, for example, enables landowners to obtain permits authorizing take of listed species incidental to otherwise lawful activities pursuant to preparation and approval of a habitat conservation plan (HCP). HCPs addressing listed or candidate fish species typically include a watershed assessment to address cumulative watershed effects, including road-related erosion and sedimentation hazards. Similarly, several private landowners are preparing either sustained yield plans (SYPs) or program timberland environmental impact reports (PTEIRs) to meet the requirements of the California Forest Practice Act regarding the maximum sustained production of high-quality forest products and minimization of significant environmental impacts. These State-level programmatic environmental compliance documents also require watershed assessments addressing cumulative watershed effects. Watershed assessments being prepared for HCPs, SYPs, and PTEIRs provide important opportunities to identify and remediate road-related watershed hazards.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Upper watershed processes (fire and erosion) are linked to Bay-Delta ecological health by affecting water supply, water quality, sediment supply, habitats, and Bay-Delta species. Healthy upper watersheds provide essential habitat conditions for anadromous fish not constrained by dams. Where dams block migration into upper watersheds healthy upper watersheds help sustain water and sediment supply and water quality, which are essential to anadromous fish in lower watersheds and floodplains below blocking dams.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for upper watershed health and function is to restore ecological processes in the upper watersheds in order to maintain and improve the quality and quantity of water flowing into the tributaries and rivers of the Sacramento-San Joaquin Delta and San Francisco Bay.

The following targets provide the general approach to restoring ecological health to upper watershed areas.

- Achieve fire fuel levels comparable to prehistoric conditions in sufficient areas so that, when large, intensive fires do occur they can, with a high degree of assurance, be contained within a single fourth-order watershed (an area of 3,000-10,000 acres).

- Use vegetation and timber management as a tool to manage natural fuel loading and fuel reduction.

- Improve drainage on all major public and private timberland in the upper watersheds.

- Replace poorly designed segments of existing forest road systems with well designed and adequately drained roads.

- Restore deteriorated watersheds, wetlands, and meadows to improve hydrologic functions of the upper watersheds.

General programmatic actions to help in achieving the targets include:

- Install a system of fuel profile zones (broad areas treated to reduce fuel loads and ladders, thus reducing fire severity and spotting potential) around forest communities to protect human life and property.

- Develop a strategy that identifies treatments that not only reduce hazards of treated areas, but also increase the defenses of adjacent areas against catastrophic fire. The strategy should also identify areas where such treatments should be applied first. For example, an extensive system of fuel breaks along ridgetops and roads could enhance the ability of fire suppression forces to protect surrounding areas.

- Prepare fuel management plans at the county or subcounty level that identify treatments, priorities, and schedules, and means to ensure the availability of adequate resources to implement the treatments.

- Implement fuel management treatments on a scale and schedule consistent with standards specified in county-level fuel management plans.

- Expand the application of prescribed natural fire, particularly on relatively remote federal forest lands.

- Increase resource allocations for fuel management without decreasing fire suppression resources to dangerous levels.

- Provide increased training in fuel management, including cross training fire suppression specialists.

- Identify means and implementation actions to expand markets for biomass materials removed from wildlands.

- Adopt more stringent requirements for slash disposal following timber harvesting.

- Refine analytical tools (e.g., landscape-level models of fire behavior) to facilitate identification of effective fuel management regimes and cost-effective strategies to implement them.

- Identify and prioritize watershed hazards that could be reduced through improved drainage.
- Conduct comprehensive road inventories on all major timberlands to identify hazardous conditions, assess the feasibility and cost-effectiveness of projects to reduce the hazards, and prioritize feasible projects for implementation.

- Decommission or obliterate obsolete roads.

- Replace streamside roads designed to facilitate tractor skidding with midslope or ridgetop roads to be used in conjunction with cable yarding systems.

- Reconstruct poorly designed road segments and install adequate drainage structures in poorly drained road segments.

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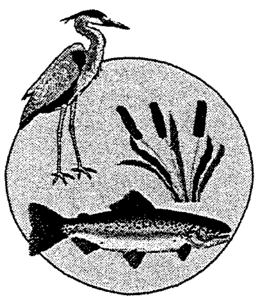
Resource Conservation District, Ukiah, CA, in cooperation with the California Department of Forestry and Fire Protection and the U.S. Soil Conservation Service.

INTRODUCTION



This section presents visions for habitat ecosystem elements. Habitats are areas occupied by plants, fish, and wildlife that provide specific conditions essential to the needs of plant and animal communities. Habitats will benefit markedly from restoration activities related to ecological processes and stressors. In some cases, direct action may be necessary to restore important habitats. Habitat types that are included are those that have a strong effect on an ecological process or a species that is dependent on the Bay-Delta and can be restored and managed to improve the health of the Bay-Delta ecosystem and its resources. Table 5 identifies important habitat ecosystem elements and the related ERPP Implementation Objective. Implementation objectives are fixed and will not change through time. Table 6 presents the basis for their consideration.

Visions describe the role and importance of each habitat type to dependent plants, fish, wildlife, and other organisms, a description of the current condition of habitats, stressors and changes to ecological processes that have altered habitat condition, and approaches for restoring habitats and their functions to improve the health of the Bay-Delta and its biological resources. The Ecosystem Restoration Program Plan (ERPP) implementation objectives, targets, and actions for each habitat type are described in "Ecosystem Restoration Program Plan, Volume II: Ecological Zone Visions". Table 7 presents the ecological zone in which implementation objectives, targets, and programmatic actions have been proposed to accomplish each habitat vision.

TABLE 5. HABITAT ECOSYSTEM ELEMENTS AND ERPP IMPLEMENTATION OBJECTIVES

Ecosystem Habitat Element	Implementation Objective
Tidal Perennial Aquatic Habitat	increase the area of shallow-water and intertidal mudflat habitat to improve conditions that support increased primary and secondary productivity; provide rearing and foraging habitat, and escape cover for fish; and provide foraging and resting habitat, and escape cover for water birds.
Nontidal Perennial Aquatic Habitat	increase its amount in the Delta to provide improved foraging and resting habitat for water birds, particularly diving ducks, and help to restore and maintain the ecological health of the terrestrial and aquatic resources in and dependent on the Delta.
Delta Sloughs	protect and improve existing tidal slough habitat and restore a portion of the historical Delta slough distribution. Sloughs will be restored within tidally influenced freshwater emergent wetlands, mudflats, and seasonal floodplains.

Midchannel Islands and Shoals	protect and enhance existing remnant channel islands in the Delta. Prioritize island restoration starting with those that have greatest chance to be maintained by restored streamflow patterns, hydraulic conditions, sediment transport, and other restored ecosystem processes.
Saline Emergent Wetland	increase the area of saline emergent wetlands. The increased wetlands area would provide high-quality habitat for waterfowl, shorebirds, and other associated wildlife; provide rearing habitat, foraging habitat, and escape cover for fish; and expand the populations and range of associated special-status and State- and federally listed plant and animal species.
Fresh Emergent Wetland	protect and enhance existing wetlands by restoring tidally influenced freshwater emergent wetland in the Delta. This protected wetland would provide high-quality habitat for waterfowl, shorebirds, and other associated wildlife and rearing, foraging, and escape cover for fish. Populations and ranges of special-status and State- and federally listed plant and animal species would be increased.
Seasonal Wetlands	restore and manage this habitat type in the Delta to help restore and maintain the ecological health of the aquatic resources in and dependent on the Delta: restore foodweb and floodplain processes; reduce the effects of contaminants and water management on the Delta's aquatic resources; and provide high-quality foraging and resting habitat for wintering waterfowl, greater sandhill cranes, and migratory and wintering shorebirds.
Riparian and Riverine Aquatic Habitats	restore riparian scrub, woodland, and forest habitat along largely nonvegetated, riprapped banks of Delta island levees, the Sacramento and San Joaquin Rivers, and their major tributaries. Restored riparian habitat would provide shaded riverine aquatic cover for fish species, associated special-status plant and animal species, and other wildlife.
Inland Dune Scrub Habitat	improve low- to moderate-quality Delta inland dune habitat to support special-status plant and animal species and other associated wildlife populations.
Perennial Grassland	preserve and restore perennial grassland habitat in conjunction with restoration of wetland and riparian habitats in order to provide high-quality habitat conditions for associated special-status plant and wildlife populations.
Agricultural Lands	co-manage agricultural upland and wetland habitat to provide wildlife forage and resting area habitat for wintering and migrating waterfowl, shorebirds, and other associated wildlife in the Delta.

TABLE 6. BASIS FOR SELECTION OF HABITAT ECOSYSTEM ELEMENTS

Ecosystem Habitat Element	Basis for Selection as an Ecosystem Element
Tidal Perennial Aquatic Habitat	Tidal perennial aquatic habitats, particularly areas less than 9 feet deep at mean high tide, are important habitat use areas for many species of fish and wildlife in the Delta. The substantial loss of historic shallow-water areas, primarily as a result of reclamation of tidally influenced habitat and channel dredging, has reduced the available habitat area for associated fish and wildlife. Loss of shallow-water areas has also caused a reduction in primary and secondary productivity which contributed to changing the historic foodweb of the Delta.
Nontidal Perennial Aquatic Habitat	Nontidal perennial aquatic habitats, particularly areas less than 6 feet deep, are important habitat-use areas for many species of fish and wildlife in the ERPP focus area. The substantial loss or degradation of nontidal perennial aquatic habitats, primarily as a result of reclamation of wetlands and alteration of streamflows, has reduced the available habitat area for associated fish and wildlife.
Delta Sloughs (Dead-end)	Dead-end sloughs provide warmer, highly productive habitat for seasonal spawning, rearing, and foraging of important aquatic organisms, as well as important carbon production for other Bay-Delta habitats. Several smaller branches of tidal slough networks have been severed from the main slough channel by levees. For waterfowl and wildlife, dead-end sloughs have associated marsh and riparian corridors important for breeding, feeding, resting, and roosting.
Delta Sloughs (Open-ended)	Open-ended sloughs provide unique, generally low-velocity habitats and important migratory pathways for many species and important habitat for wildlife and waterfowl along the riparian corridors of the sloughs. Levee construction and channel dredging over many years has converted the gradual sideslopes supporting marsh and tideflat habitat along sloughs to steep-sided, high-velocity channels with narrow or nonexistent shoreline habitat.
Midchannel Islands and Shoals	Midchannel islands and shoals provide unique remnant shallow-water edge habitat in many Delta channels. They typically support willow scrub, tule marsh, and tidal mudflat habitats and associated wildlife and fish. Midchannel islands and shoals have been shrinking or disappearing as a result of progressive erosion. Loss of this habitat has reduced nutrient cycling, and foodweb support functions in the ERPP focus area.

Table 6. Continued

Ecosystem Habitat Element	Basis for Selection as an Ecosystem Element
Saline Emergent Wetland	Saline emergent wetland habitats, including brackish and saline wetlands, are important habitat-use areas for fish and wildlife dependent on marshes and tidal shallows in the Bay-Delta and support several special-status plant species. The loss or degradation of historic saline emergent wetlands, primarily as a result of reclamation of tidally influenced wetlands for agriculture, has substantially reduced the habitat area available for associated fish and wildlife species. Several plant and animal species closely associated with tidal saline emergent wetlands have been listed as endangered under the State and federal Endangered Species Acts, primarily as a result of the extensive loss of this habitat type. Loss of this habitat has reduced nutrient cycling, and foodweb support functions in the ERPP focus area.
Fresh Emergent Wetland	Tidal and nontidal fresh emergent wetland habitats are important habitat-use areas for fish and wildlife dependent on marshes and tidal shallows in the ERPP focus area and support several special-status plant species. The loss or degradation of historic fresh emergent wetlands has substantially reduced the habitat area available for associated fish and wildlife species.
Seasonal Wetlands	Seasonal wetland and aquatic habitats are important habitat-use areas for many species of fish and wildlife in the ERPP focus area. Loss or degradation of historic seasonal wetlands, primarily as a result of urban development and reclamation of wetlands for agriculture, has substantially reduced the habitat area available for waterfowl, shorebirds, and other water birds. Loss of vernal pool habitat, in particular, has directly resulted in the listing of several vernal pool-dependent species as threatened or endangered under the federal Endangered Species Act. The loss of seasonal aquatic floodplain habitat, primarily as a result of levee construction and alteration of riverflows, has substantially reduced floodplain refuge habitat for fish and spawning habitat for the Sacramento splittail. Loss of this habitat has reduced water storage, nutrient cycling, and foodweb support functions in the ERPP focus area.
Riparian and Riverine Aquatic Habitats (Shaded riverine aquatic)	Shaded riverine aquatic habitat (SRA) is a major component of the ERPP riparian and riverine aquatic habitat ecosystem element. SRA habitats are important habitat areas for one or more life stages of most fishes that inhabit the ERPP focus area. The loss or degradation of historic riparian vegetation from river and stream channelbanks and alteration of nearshore aquatic habitat have primarily been caused by channelization, stabilization of channelbanks with riprap, and construction of levees. Control of flows and diversion of water have altered the hydrologic conditions that historically supported riparian vegetation. The loss of SRA has directly contributed to declines in populations of associated native fishes and reduced an important source of nutrients and allochthonous material in streams and Delta sloughs.

Table 6. Continued

Ecosystem Habitat Element	Basis for Selection as an Ecosystem Element
Riparian and Riverine Aquatic Habitats (Riparian scrub, woodland, and forest habitat)	Riparian scrub, woodland, and forest habitat is the other major component of the riparian and riverine aquatic habitat ecosystem element. Many species of wildlife, including several species listed as threatened or endangered under the State and federal Endangered Species Acts and several special-status plant species in the ERPP focus area are dependent on or closely associated with riparian habitats. Compared with all other habitat types in California, riparian habitats support the greatest diversity of wildlife species. Degradation and loss of riparian habitat have substantially reduced the habitat area available for associated wildlife species. Loss of this habitat has reduced nutrient cycling, and foodweb support functions in the ERPP focus area. Valley oak woodland habitats are important habitat-use areas for many species of wildlife in the ERPP focus area. The loss or degradation of historic stands of valley oak woodland has substantially reduced the valley oak woodland habitat area available for associated wildlife.
Inland Dune Scrub Habitat	Coastal scrub is associated with inland sand dunes and is limited in the ERPP focus area to the vicinity of the Antioch Dunes National Wildlife Refuge. This habitat area supports two plant and one butterfly species listed as endangered under the federal Endangered Species Act.
Perennial Grassland	Grasslands are important breeding and foraging habitat areas for many species of wildlife and support several special-status plant species. Historically common throughout most of the Central Valley, most perennial grassland in the ERPP focus area has been lost or has been converted to annual grassland.
Agricultural Lands (Agricultural wetlands)	Following extensive loss of native wetland habitats in the ERPP focus area, some wetland-associated wildlife species have adapted to the artificial wetland environment created by some agricultural practices and have become dependent on agricultural wetland areas to sustain their populations at current levels. Agricultural wetlands include rice lands; fields flooded for weed, salinity, and pest control; stubble management; and tailwater circulation ponds.
Agricultural Lands (Agricultural uplands)	Following extensive loss of some native upland habitats, upland-associated wildlife species have adapted to the artificial upland environment created by some agricultural land uses and have become dependent on agricultural upland areas and fence line vegetation to sustain their populations at current levels.

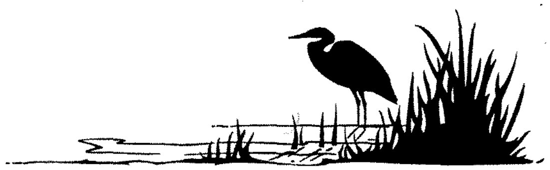
TABLE 7. ECOLOGICAL ZONES IN WHICH HABITAT IMPLEMENTATION OBJECTIVES, TARGETS, AND PROGRAMMATIC ACTIONS ARE PROPOSED

[Note: Refer to Volume II: Ecological Zone Visions for information regarding specific targets and actions.]

Habitat Vision	Ecological Zone[1]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Tidal Perennial Aquatic Habitat	•	•												
Nontidal Perennial Aquatic Habitat	•	•												
Delta Sloughs	•	•												
Midchannel Islands and Shoals	•													
Saline Emergent Wetland		•												
Fresh Emergent Wetland	•													
Seasonal Wetlands	•	•				•	•	•	•		•	•		•
Riparian and Riverine Aquatic Habitats	•	•	•	•	•	•	•	•	•	•	•	•	•	•
Inland Dune Scrub Habitat	•													
Perennial Grassland	•	•							•					
Agricultural Lands	•					•	•	•	•	•		•		•

Ecological Zones

[1] 1 = Sacramento-San Joaquin Delta
2 = Suisun Marsh/North San Francisco Bay
3 = Sacramento River
4 = North Sacramento Valley
5 = Cottonwood Creek
6 = Colusa Basin
7 = Butte Basin
8 = Feather River/Sutter Basin
9 = American River Basin
10 = Yolo Basin
11 = Eastside Delta Tributaries
12 = San Joaquin River
13 = East San Joaquin Basin
14 = West San Joaquin Basin



INTRODUCTION

Tidal perennial aquatic habitat consists of the estuary's edge waters, mudflats and other transitional areas between open-water habitats and wetlands. These shallow waters are associated with natural wetland and riparian habitats that are so important to fish and wildlife of the Bay-Delta. The substantial loss of historic shallow tidal waters, primarily as a result of reclamation and channel dredging and scouring, has led to the decline of many native fish, wildlife, and plant species in the Bay-Delta. Loss of such habitat has also reduced primary (plant) and secondary (invertebrate) productivity in the Bay-Delta estuary, and has changed important characteristics of the natural foodweb of the system.

RESOURCE DESCRIPTION

Tidal perennial aquatic habitat is important for many fish, wildlife, and plants. It also supports many biological functions important to the Bay-Delta system. Many animal and plant species, identified as threatened or endangered under the California and federal Endangered Species Acts (ESAs), rely on tidal perennial aquatic habitat during some portion of their life cycle.

Bay-Delta estuary tidal wetlands and associated perennial aquatic habitat are among the most valuable natural resources in the United States. Restoring tidal perennial aquatic habitats is an important ingredient for successfully restoring the Bay-Delta. Tidal aquatic habitats link wetlands with open-water habitats. Such habitat is used as foraging and resting habitat and escape cover for shorebirds, wading birds, and waterfowl. Resident and migratory fish use tidal perennial aquatic habitats for spawning, rearing, foraging, and escape cover. Young salmon forage in these productive waters and put on critical weight before entering the ocean. Striped bass, delta smelt, splittail, and many native resident Bay-Delta fish use this habitat, especially as rearing areas.

Tidal perennial aquatic habitat plays a primary role in the formation and maintenance of tidal wetlands. As tidal aquatic habitats accumulate sediment vegetation can increase. Over time this vegetation will become wetland and riparian habitat. As these tidal aquatic habitats accumulate sediment and vegetation, they maintain their structure and function, even with gradual rises in sea level.

Stressors that adversely affect the health of tidal perennial aquatic habitats include urban and industrial development, dredging, levees and associated land conversion, wastewater discharges, and land, urban and agricultural runoff.

VISION

The vision for tidal perennial aquatic habitats is to restore large areas of connecting waters associated with tidal emergent wetlands and their supporting ecosystem processes. Achieving this vision will assist in the recovery of special-status fish populations and provide high-quality aquatic habitat for other fish and wildlife dependent on the Bay-Delta. Restoring tidal perennial aquatic habitat would also result in higher water quality and increase the amount of shallow-water and mudflat habitats; foraging and resting habitats and escape cover for water birds; and rearing and foraging habitats, and escape cover for fish.

Reducing fragmentation of existing tidal perennial aquatic habitat should be a focus of restoration efforts. Many areas of open water in the Bay-Delta are isolated by levees or deeper open-water habitat. Many open-water areas have been converted to managed marshes, saltponds, or agricultural use. Restoring historic habitats would involve reclaiming former tidal habitat by levee removal.

Initial efforts should focus on protecting existing tidal perennial aquatic habitats. These existing habitats offer functions and values that may not be possible to recreate. Former habitats should be linked with existing healthy habitats to enhance natural habitat restoration. Restored habitats should have natural gradients of open water, shallow water, wetland, riparian, and upland habitats to increase the habitat value for a greater diversity of species.

Many leveed lands in the Bay and Delta have subsided and are too low to support shallow tidal perennial aquatic habitat, and thus cannot be readily restored. The greatest subsidence has occurred in the Central and West Delta Ecological Unit. A comprehensive long-term program is needed to reverse subsidence. Changes in land use management, and use of suitable dredged materials or other "natural materials" should be implemented to restore land elevations to suitable ranges.

Restoration efforts should focus on those leveed lands that have not yet been subjected to severe subsidence. Prime candidates are existing managed marshes and salt ponds adjacent to San Pablo and Suisun Bays. Leveed agricultural lands and some industrial lands adjacent to Suisun Bay can be readily restored to tidal aquatic habitat. Some of the habitat would be mudflats, while deeper waters would be shallow productive bays not unlike the very productive Honker and Grizzly Bays of Suisun Bay, and much of northern San Pablo Bay.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Many programs and projects aim to protect, restore, and enhance the San Francisco-San Joaquin Bay-Delta estuary. These include:

- the Bay Area Aquatic Habitats Planning Group;
- Cache Creek Corridor Restoration Plan;
- California Wetland Riparian Geographic Information System Project;
- Central Valley Habitat Joint Venture;
- Governor's California Wetland Conservation Policy;
- Inland Wetlands Conservation Program;
- Montezuma Wetlands Project;
- National Estuarine Reserve Research System;
- North American Waterfowl Management Plan;
- North Bay Initiative;
- North Bay Wetlands Protection Program,
- San Francisco Bay Regional Water Quality Control Board, and San Francisco Bay Conservation and Development Commission - Regional Wetlands Management Plan;
- San Francisco Estuary Project;
- Suisun Ecological Workgroup of the Interagency Ecological Program;
- Tidal Wetlands Species Recovery Plan;
- Wetlands Reserve Program;

- and Yolo Basin Wetlands Project.

The Ecosystem Restoration Program Plan restoration targets and objectives reflect the goals of many of these programs. For example, the San Francisco Bay Area Wetlands Ecosystem Goals Project currently underway is a comprehensive science-based approach to determining where, how much, and what kinds of wetlands should be restored in the Suisun Bay and San Francisco Bay areas. Contributing to each of these program would help to restore critical ecological processes, functions, and habitats and reduce or eliminate stressors.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Tidal perennial aquatic habitat is linked to the following ecosystem elements: (1) ecological processes, (2) habitats, (3) species, and (4) stressors.

Related ecological processes include Delta inflow (Central Valley streamflows) which influences the location of the entrapment zone; natural sediment supply which influences the maintenance of mudflats, shallow shoals, bottom composition throughout the Delta and Bay; Bay-Delta hydraulics which influences flow patterns in channels and sloughs; and Bay-Delta aquatic foodweb which depends on nutrient input, shallow water interactions, and access to tidal perennial habitat.

Habitats which are closely linked to tidal perennial aquatic habitat include tidal sloughs and channels, saline emergent wetlands, midchannel islands and shoals, and perennial grasslands. Tidal perennial aquatic habitat also provide an important ecological connection between open-water areas and shallow-water, emergent wetlands, and riparian habitats.

Species which depend on tidal perennial aquatic habitat include a large assemblage of marine, estuarine, anadromous, and resident fish, wildlife, and plant species and communities.

Stressors which adversely effect tidal perennial aquatic habitat include levee construction, contaminants, and dredging and sediment disposal.

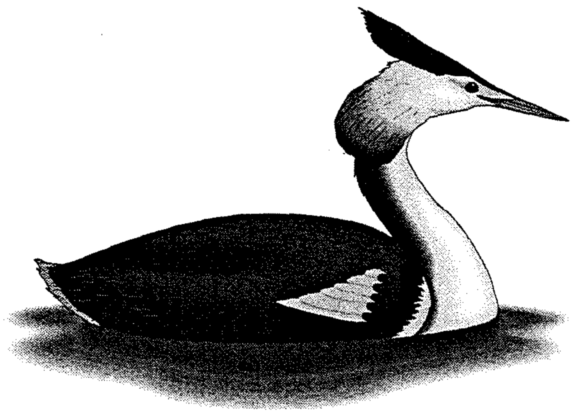
IMPLEMENTATION OBJECTIVE, TARGETS AND PROGRAMMATIC ACTIONS

The implementation objective for tidal perennial aquatic habitat is to increase the area of shallow-water and intertidal mudflat habitat to improve conditions that support increased primary and secondary productivity; provide rearing and foraging habitat, and escape cover for fish; and provide foraging and resting habitat, and escape cover for water birds.

The general target for restoration of tidal perennial aquatic habitat is to restore 7,000 acres in the Sacramento-San Joaquin Delta Ecological Zone and 2,500 acres in the Suisun Marsh/North San Francisco Bay Ecological Zone.

The following actions will help achieve this vision:

- restoring land elevations will allow more leveed lands to be returned to tidal shallow water habitat,
- setting backs levees would add aquatic habitat along potential margins of the Bay and Delta, and
- opening or breaching levees would also open unnaturally isolated lands to tidal flows.



INTRODUCTION

Nontidal perennial aquatic habitat in the Bay-Delta estuary is present in certain low-elevation areas. Such areas have permanent open water which is no longer subject to tidal influence. The size, quantity, and quality of existing nontidal perennial habitat do not equal the wildlife habitat values of sloughs and backwaters in the estuary before reclamation.

Nontidal perennial aquatic habitats are important for many species of wildlife in the Delta. In many places within the Delta, nontidal aquatic habitat has replaced the native tidal aquatic habitats. Outside the Delta, the substantial loss or degradation of nontidal aquatic habitats associated with Central Valley wetlands has reduced the available habitat area for many native fish and wildlife species. Land reclamation is the major factor that limits the contribution of nontidal perennial aquatic habitats to the health of the Delta.

RESOURCE DESCRIPTION

Historically, most wetlands in the Bay-Delta estuary were tidal. Nontidal perennial aquatic habitats were largely nonexistent. Some historical nontidal perennial habitat was created naturally. Shifts in river alignments occasionally isolated oxbow lakes, and drainage divide ponds in Bay area tidal wetlands were subjected to limited tidal action. Most of the remaining nontidal perennial aquatic habitat areas were established by constructing dikes and levees.

Isolating these areas allowed their conversion for other uses, primarily agricultural. Perennial aquatic habitats on converted lands are primarily located in large agricultural drains, small farm ponds, industrial ponds, ponds managed for waterfowl and other wildlife, and Delta island blowout ponds (created by levee failures that scour island interiors deeply enough to maintain permanent water through seepage).

Existing nontidal open-water areas generally have poor wildlife value. Nontidal perennial aquatic habitats have insufficient shoreline cover for nesting and protection from predators. Adjacent lands are relatively barren (e.g., farmed fields and land next to industrial ponds) and lack cover needed by nesting waterfowl and other species that require adjacent open-water and upland habitats. A notable exception is the unreclaimed blowout ponds around which native vegetation has been allowed to establish (e.g., ponds on Webb Tract).

The loss of permanent open water within historic tidal wetlands substantially reduced habitat for waterfowl, shorebirds, and other wetland wildlife species in the Bay-Delta system. Important ecosystem processes needed to restore and sustain nontidal perennial aquatic habitat include:

- the geologic and hydrologic condition, stream meander, and tidal function necessary to maintain permanent surface water;
- a range of elevations sufficient to support deep-water (greater than 3 feet in depth) and shallow-water areas; and

- adjacent wetland and riparian (streambank) vegetation.

Land use and human disturbance are stressors on nontidal perennial aquatic habitat. Insufficient buffer areas around open water reduce habitat value for wildlife species. These species require quality upland habitats connected to the aquatic habitat and increasing levels of human disturbance that adversely affects wildlife using open-water areas.

The value of open-water habitat to wildlife greatly increases if emergent vegetation is present along shorelines and in shallow-water areas. Adjacent dense upland herbaceous vegetation and riparian woodland further increase the value to wildlife.

VISION

The vision for nontidal perennial aquatic habitat is to increase open-water areas to provide high-quality habitat for waterfowl and other water birds. This vision can be achieved as a component of saline and freshwater emergent wetland restorations.

Permanent open-water areas could be restored as a component of nontidal saltwater, and fresh emergent wetland habitat areas. The bottom slope ranges of restored wetland areas will provide the water flow patterns necessary to create a wide variety of permanent open-water areas. Waterfowl brood ponds can be constructed on agricultural lands next to suitable waterfowl nesting habitats.

Restoring nontidal perennial aquatic habitat would improve ecological process and functions of other habitats and wildlife. Adjacent wetland and upland habitats would then have increased ecological value. The open shallow water would provide resting and foraging habitat for waterfowl and other water birds. Wading and shore birds would feed in the open shallow water habitat. These restored habitats may improve the quantity and quality of nesting habitat. Increased nesting habitat would increase the production of waterfowl and other water birds in the estuary.

Restoring nontidal perennial aquatic habitat in sufficient quantity and quality will require reestablishing associated ecosystem processes. Restoring these processes will establish and maintain habitat, reduce or remove stressors, and help restore adjacent habitats.

Restoration efforts should be accomplished through landowners, conservation groups, and land management agencies. The focus of these efforts should be to restore open-water habitats on Delta islands and other former tidelands of the Bay-Delta.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore fresh emergent wetland habitat would involve cooperation with other wetland restoration and management programs. These include:

- Agricultural Stabilization and Conservation Service's Wetland Reserve Program,
- Wildlife Conservation Board's Inland Wetlands Conservation Program,
- restoration programs administered by Ducks Unlimited and the California Waterfowl Association,
- Central Valley Habitat Joint Venture and North American Waterfowl Management Plan,
- the Suisun Marsh Protection Plan,
- and ongoing management of State and federal wildlife refuges and private duck clubs.

Cooperation will also be sought from agencies or organizations with responsibility or authority for restoring wetland and aquatic habitats, including

California Department of Fish and Game, California Department of Water Resources, U.S. Fish and Wildlife Service, the U.S. Army Corps of Engineers, and the Delta Protection Commission.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Nontidal perennial aquatic habitat is linked to the following ecosystem elements: (1) ecological processes, (2) habitats, (3) species, and (4)stressors.

Related ecological processes include:

- natural geologic and hydrologic conditions,
- stream meander corridor,
- and tidal actions that maintain permanent water.

Other areas which are closely linked to nontidal perennial aquatic habitat include:

- adjacent wetlands and upland habitats,
- and riparian and riverine aquatic habitat.

Species which depend on nontidal perennial aquatic habitat include:

- resident fish and wildlife,
- migratory birds,
- and plant species and communities.

Stressors which adversely effect nontidal perennial aquatic habitat and wildlife use include:

- levee construction,
- land use,
- loss of edge vegetation,
- and human disturbance.

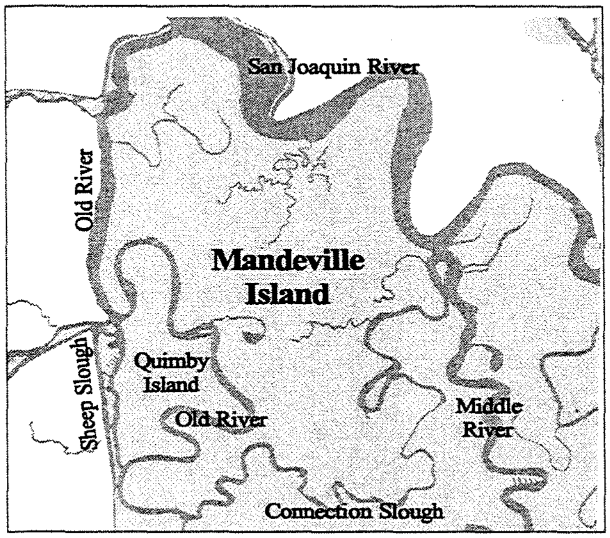
IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for nontidal perennial aquatic habitat is to increase its amount in the Delta to provide improved foraging and resting habitat for water birds, particularly diving ducks, and help to restore and maintain the ecological health of the terrestrial and aquatic resources in and dependent on the Delta.

The general target for restoring nontidal perennial aquatic habitat is to provide 500 acres in the Sacramento-San Joaquin Delta Ecological Zone and 500 acres in the Suisun Marsh/North San Francisco Bay Ecological Zone.

The following actions would help to achieve targets for nontidal perennial aquatic habitat restoration:

- Restore nontidal perennial aquatic habitat in concert with restoration of fresh emergent wetland habitats.
- Restore permanent open-water areas by establishing elevation gradients sufficient to maintain surface water through natural groundwater or surface-water recharge, or by pumping water into lowland areas.



INTRODUCTION

Sloughs are a small remaining part of natural Delta habitats. Sloughs are tidal channels of the Delta that once connected rivers to the Bay through Delta marshes. These low-velocity, natural tributaries of Delta rivers vary in depth and width, have gently sloped, vegetated sides, and are connected to the Delta.

Most of the Delta sloughs were lost when the islands were reclaimed by construction of the levees. Many smaller Delta sloughs were lost in the past several decades when levees severed them from main channels. Levee construction and maintenance along sloughs has reduced the habitat value of many natural sloughs in the Delta. Boat traffic has also lead to shoreline erosion and loss of shallow water, marsh, and riparian habitat along many sloughs.

Sloughs provide warmer, highly productive habitat for seasonal spawning, rearing, and foraging for many aquatic organisms, as well as important organic carbon productivity for all habitats of the Bay-Delta. Sloughs provide shallow, low-velocity refuge habitat for many native fishes. Slough habitat also includes associated marsh and riparian (streambank) corridors that are important for breeding, feeding, resting, and roosting waterfowl. Several resident species of Delta fish live in sloughs, and splittail and delta smelt may use them for spawning. Unlike leveed river channels, sloughs have marsh and riparian fringes with shallow water and natural shaded riverine aquatic habitat.

RESOURCE DESCRIPTION

Delta sloughs provide various beneficial habitats. They offer protection to plants, fish, and wildlife from wind and high-velocity flows. Delta sloughs support floating aquatic plant communities, which are otherwise found only in small, sheltered pockets along open channels. The seasonal succession of native floating plants in sloughs is a valuable link in the estuary's food chain. First to appear is duckweed, which provides primary food production for insect larvae, crustaceans, and waterfowl and other birds. The duckweed community creates conditions favorable to water fern establishment. The water fern's pores contain a bacterium that photosynthesizes and "fixes" (stores) nitrogen, which allows the water ferns to establish in nitrogen-deficient waters. Aquatic plants in sloughs provide protective cover for fish; habitat for insects, fish, and birds; and an abundance of food organisms. Wildlife use varies with the amount of open water and marsh, the extent and type of vegetation present, and surrounding land uses.

Delta sloughs provide habitat for biological functions necessary for the survival of resident and migratory fish species. These species need Delta slough's warm, highly productive habitat for seasonal spawning, rearing, and foraging. Organic carbon created by the sloughs helps other Bay-Delta habitats.

Adjacent marsh and riparian corridors provide breeding, feeding, resting, and roosting habitat for waterfowl and wildlife. Delta sloughs and their riparian scrub, riparian forest, and open-water habitats provide the complex habitat needed by some State- and federally listed species such as the giant garter snake, splittail, and delta smelt.

Dead-end sloughs include Beaver, Hog, and Sycamore Sloughs. These quiet backwaters provide essential habitat for native resident fish. Open-ended sloughs provide unique, generally low-velocity habitats and migratory pathways for many species. In addition, the adjacent riparian corridors provide habitat for wildlife and waterfowl.

Sloughs provide valuable transitional zones that link upland terrestrial habitats with open-water habitats. Historically, these transitional areas provided foraging, resting, and escape cover for shore and wading birds and other waterfowl. Resident and migratory fish use sloughs for rearing, foraging, and escape cover.

The ability of most sloughs to provide these functions has been severely degraded. Urban and industrial development has moved into areas adjacent to sloughs, destroying historic riparian habitat. Other factors that have contributed to degradation of habitat values include invasion and spread of non-native aquatic plants, such as water hyacinth, reduced water quality, and reduced freshwater outflows. In addition, levee construction and channel dredging have converted gradual sideslopes that once supported marsh and tidal flat habitat into steep-sided, high-velocity channels with narrow strips of emerging shoreline habitat.

VISION

The vision for Delta sloughs is to increase the area of high-quality interconnected dead-end and open-ended Delta sloughs. Achieving this vision will assist in the recovery of special-status fish and wildlife populations, provide shallow-water habitats for fish spawning and rearing, and provide aquatic, wetland, and riparian habitat for wildlife. Existing sloughs would be protected and enhanced and the area of tidal slough habitat would be increased.

Existing natural sloughs require protection and habitat improvement. Additional restoration efforts would be identified by developing a thorough understanding of site-specific sediment transport, tides, hydrogeomorphology (landscape forms created by moving water), and Delta channel hydraulics (water flow patterns). Restoration of a variety of slough and adjacent terrestrial and aquatic areas would provide a wide range of complex habitats that would benefit many aquatic and terrestrial species.

Changes in tidal flows through sloughs and decreased human disturbance (e.g., reduced wake erosion) could improve slough habitat. Removing invasive, non-native aquatic plants would help restore many smaller sloughs to their natural function.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Many projects associated with wetlands would benefit open-ended and dead-end sloughs. Some of these are sponsored by:

- San Francisco Estuary Project, Bay Area Wetlands Planning Group,
- California Wetland Riparian Geographic Information System Project,
- Governor's California Wetland Conservation Policy,
- Inland Wetlands Conservation Program,
- North Bay Wetlands Protection Program,

- San Francisco Estuary Project,
- and Wetlands Reserve Program.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Delta sloughs are linked to the following ecosystem elements: (1) ecological processes, (2) habitats, (3) species, and (4) stressors. For example sloughs an important element in Delta channel hydraulic, provide a range of aquatic habitats from deep water to tidal emergent vegetation and supports riparian vegetation. Many resident fish species, invertebrates, reptiles and amphibians utilize these habitats, as well as resident and neotropical migratory birds, and waterfowl.

Maintenance and restoration of Delta and other tidal slough are dependent on channel hydraulics; natural sediment supply, sediment transport, erosion, and deposition; and tides.

Other habitats that are interconnected to Delta and other tidal sloughs include open water areas, tidal perennial aquatic habitat, mainstem rivers, emergent wetlands, mudflats, seasonal floodplains, and riparian and riverine aquatic habitats.

Stressors to the health and quality of slough habitats include levee and channel island erosion, increased water velocities, and the removal of overhanging vegetation.

IMPLEMENTATION OBJECTIVES, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objectives for Delta sloughs are to protect and improve existing tidal slough habitat and restore a portion of the historical Delta slough distribution. Sloughs will be restored within tidally influenced freshwater emergent wetlands, mudflats, and seasonal floodplains. Healthy sloughs will help restore and maintain the ecological health of the aquatic resources in and dependent on the Bay Delta.

The general target for restoration of Delta sloughs it to restore 160 miles in the Sacramento-San Joaquin Delta Ecological Zone and 30 miles of tidal sloughs in the Suisun Marsh/North San Francisco Bay Ecological Zone. The restoration of Delta sloughs will, in many instances, be closely linked to the restoration of tidal perennial habitat, and fresh and saline emergent marshes. In developing the approach to habitat restoration, a mosaic of habitats is very desirable, including provisions for increasing the overall linear mileage of Delta sloughs.

Actions that could be taken to improve slough habitat in the Delta include the following:

- Protect existing dead-end and open-ended sloughs from possible future degradation through cooperative agreements with land management agencies or conservation easements or purchase from willing sellers.
- Restore hydrologic conditions necessary for establishing Delta sloughs by constructing setback levees, removing dikes, constricting slough openings, and managing flows through Delta channels.
- Where consistent with flood control objectives, modify vegetation management practices along levees adjacent to sloughs to allow wetland vegetation to reestablish naturally.
- Identify and implement solutions to levee and channel island erosion that do not remove shallow-water habitat, increase water velocities, or remove overhanging vegetation.
- Reduce the adverse effects of boat wakes in sensitive habitat areas by excluding boats from

certain areas at certain times and establishing maximum speed limits.

- Restore connectivity between high-quality habitats through cooperative agreements with land management agencies or through conservation easements or purchase from willing sellers.

- Where possible create new slough habitat where tidal saline and freshwater emergent wetlands are created in the Bay and Delta.

INTRODUCTION

Midchannel islands and shoals provide unique remnant shallow-water habitat in many Delta channels. They typically support tule marsh, and to a lesser extent willow scrub, tidal mudflat habitats and associated wildlife and fish. Some midchannel islands have small, remaining riparian woodlands with oaks, cottonwoods, alders, and willows.

Midchannel islands and shoals have been shrinking or disappearing as a result of progressive erosion of the remaining habitat. Loss of islands and shoals affects fish and wildlife habitat, and foodweb productivity. Major factors contributing to the loss of midchannel islands and shoals are gradual erosion from channels conveying water across the Delta to south Delta pumping plants, boat wakes, and dredging within the Delta or on adjacent waters.

RESOURCE DESCRIPTION

Midchannel islands and adjacent shoals provide shallow-water edge, riparian scrub, and emergent marsh habitat in selected Delta channels. The midchannel islands in some Delta locations retain many of these qualities because of their relative isolation. In other channels, high water velocities, heavy use for boating, and associated wave-induced erosion have degraded these islands. Many of the Delta channels and their midchannel islands and shoals are changing rapidly because of increased wakes from boats and changes in water velocities.

Midchannel islands vary in size, shape, and elevation, creating a diversity of habitat types and associated wildlife benefits. Protecting midchannel islands and shoals will help improve the overall quality and diversity of Bay-Delta aquatic habitats. Improving the productivity of the Bay-Delta aquatic habitat foodweb is needed to support the sustainable production and survival of fish.

The Delta formerly supported broad expanses of tule marshes, riparian forests, and shallow-water habitats. Today, most of these habitats have been replaced by intense agricultural production on levee-bounded islands. Delta islands are separated by steep-banked waterways, which provide few shallow-water areas where natural vegetation can take root. Natural vegetation is generally limited to midchannel islands and a narrow band along levee edges. In many areas, even this remaining band of vegetation has been displaced by bank protection. Cumulative loss of natural vegetation has a detrimental impact on the Delta's fish and wildlife populations.

Midchannel islands and shoals in the Delta are the remnants of naturally occurring islands that existed prior to reclamation or are remnants of natural or old levees. The islands are what remains of an expanse of tule marsh with largely shallow and diffuse channels separating the stands. Early efforts to convert the Delta islands into agricultural lands included dredging in the vicinity of these islands for material to form levees. At first, dredging was simple because most of the excavated land was intertidal marsh. While converting the marsh to agriculture lands, naturally meandering channels were straightened, resulting in the creation of tule islands. In other areas, the distance between levees was wide and marsh was left between the levees. The sizes of these remainders varied considerably.

Midchannel islands and their adjacent shoals present a wide array of physiographic types and include a wide variety of habitats. Island habitats range from small tule islands that are essentially freshwater marshlands to large upland sites with riparian woodland, dredge spoils, brushland, ponds, and a variety of marsh types.

An important attribute of these islands is their isolation from mainland activities. Isolation turns these islands into wildlife refuges during spring and summer months when recreational use of the Delta is at its peak.

Midchannel islands and shoals provide valuable riverine-edge and shallow-water habitat within main channels. Actual descriptions of midchannel islands would have to be made on a site-by-site basis, since their physical features depend on parameters such as elevation, size, location, and amount of human disturbance. The island's isolation from human disturbance and the amount of disturbance to the terrestrial-aquatic interface determine the value of midchannel islands to wildlife, especially listed species.

Midchannel islands and shoals are important components of the landscape and contribute to the health of the Bay-Delta. Other important ecological functions influencing Bay-Delta health include natural sediment supply, aquatic habitat, nutrient input, and areas of primary (plant) and secondary (invertebrate) production. Various life stages and species of fish require a variety of habitats and the ability to move between habitat patches. Habitat variations and access are important for the reproduction and survival of fish in flowing water ecosystems. Shallow water habitat in the Delta is predominantly found along levees, islands, and shoals. The terrestrial-aquatic (land-water) interface provides habitat diversity, a large supply of organic matter, and shallow habitats with few aquatic predators. Most Delta-spawning fish spawn in shallow water.

Human activities on stream ecosystems are typically concentrated at the terrestrial-aquatic interface. Shallow water land uses decrease the diversity and connectivity of physical habitats. The result of these alterations is a reduction in fish diversity, a shift in fish trophic structure, and an increase in temporal variability of fish abundance in water ecosystems.

The terrestrial-aquatic interface experiences extreme physical-chemical variability when hydraulic conditions fluctuate. Floodflows are confined by levees and bank protection structures. Fluvial energy increases flows that scour and cut into the midchannel islands and shoals.

The main concern regarding midchannel islands is the rate at which they appear to be eroding. Midchannel islands are built up by sediment deposits and reduced by erosion. Reduction of flow or sediments reduces or halts the rate of midchannel island formation. Some waterways within the Delta lack sufficient sediment, while in other areas, erosion exceeds deposition. Lack of sediment supply to the Delta causes midchannel islands and shoals to erode, decreasing both the quality and quantity of island and shoal habitat. Dredging the shoals immediately adjacent to channel islands undermines the structural stability of the islands and subjects them to slumping and increased erosion. Boat wakes and boat-related recreational activities play a large role in the increased rate of erosion.

VISION

The vision for midchannel islands and shoals is to protect them to provide high-quality habitat for fish and wildlife dependent on the Bay-Delta.

Restoring midchannel islands is dependent on local hydrologic conditions (e.g., water depth, water velocity, and wave action). Depositing sediment necessary for establishing and maintaining shoals and terrestrial-aquatic interfaces will help rebuild the islands and reduce harmful erosion. Preserving midchannel island isolation will protect the islands and shoals from further damage and allow for natural habitat restoration.

Direct restoration of midchannel islands and shoals will be the primary approach to achieving this vision. The primary method of restoring midchannel islands would be to protect and improve existing channel islands. Restoration should include reconstructing the natural flows and velocities that provided consistent and predictable flows and sediments. Consequently, sediment supply must be restored to that which formed islands, shoals, and habitat for native fish and wildlife.

Reducing erosion rates and offsetting erosion losses would reduce the effects of major stressors on these islands. Reducing boat wakes and excessive channel velocities will allow deposits and wetlands to establish.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

The U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service Deep Water Ship Channel Monitoring Program was a project to provide information to successfully design and create wetland habitats in the Delta. The project deposited dredged spoils to create new shallow-water, wetland, and upland habitats within two flooded islands in the Sacramento-San Joaquin Delta. The Levee Subvention Program demonstration projects for erosion control and habitat establishment is another related effort.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Midchannel islands and shoals are linked to other ecosystem elements including (1) ecological processes, (2) habitat, (3) species, and (4) stressors. Ecological processes include contribution to the Bay-Delta aquatic foodweb and natural sediment supply which helps to maintain channel islands.

Midchannel islands and shoals provide riverine-edge habitat, shallow-water habitat, escape cover for young fish and wildlife, riparian and riverine aquatic habitat, and mudflats. Numerous aquatic and terrestrial fish, wildlife, and plant species rely on the complex array of habitats provided by this type of habitat.

Erosion seems to be the major stressor that is impairing the ecological health of this resource. This erosion is a result of wind-driven and boat wake wave erosion and high channel water velocities.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for midchannel islands and shoals is to protect and enhance existing remnant channel islands in the Delta. Prioritize island restoration starting with those that have greatest chance to be maintained by restored streamflow patterns, hydraulic conditions, sediment transport, and other restored ecosystem processes.

The general restoration target for midchannel islands and shoals are restore and maintain 50-200 acres of high quality midchannel islands and shoals.

The following actions would help to protect and restore channel islands and shoals:

- Implement restoration projects currently proposed in the Delta by resource and cooperating agencies.
- Develop and implement an inventory and assessment of the existing midchannel Delta

islands. Use this information to develop long-term actions to protect and enhance the islands.

- Install structures, such as floating booms, to weaken the force of waves to reduce midchannel erosion in sensitive areas.

- Reduce boat traffic near high quality midchannel islands.

INTRODUCTION

Saline emergent wetland habitats are located on the western edge of the Delta and in Suisun Marsh on the Bay. Saline emergent wetland habitats, including brackish and saline wetlands, are important habitats for fish and wildlife that are dependent on marshes and tidal shallows.

Saline emergent wetland habitats also support several special-status plant species. The loss or degradation of historic saline emergent wetlands has substantially reduced the habitat area available for associated fish and wildlife species. Several plant and animal species closely associated with tidal saline emergent wetlands have been listed as endangered under the State and federal Endangered Species Acts, primarily as a result of the extensive loss of this habitat type. Major factors that limit this resource's contribution to the health of the Delta are related to harmful effects of saline emergent wetlands conversion for agricultural, industrial, and urban uses.

RESOURCE DESCRIPTION

Saline emergent wetlands were once continuous from San Francisco Bay into the western Delta. Saline emergent habitat also is found in low-elevation areas of the Central Valley where salts have accumulated and groundwater is near the surface. Most remnant tidal saline emergent wetlands are narrow bands along the margins of San Pablo Bay and Suisun Marsh and Bay. Extensive relict tidal marshes are associated with Cutoff Slough and eastern Hill Slough flank the Potrero Hills in the north central Suisun Marsh and are especially unique in that there is a wetland continuum from tidal slough through low, middle, and high marsh zones and into adjacent uplands which are rich with associated vernal pools.

Land use changes over the past century have reduced the amount of saline emergent wetland habitat and fragmented what was once nearly contiguous habitat. In particular, diking of historic wetlands has substantially reduced the amount of tidally influenced saline emergent wetlands. Large areas of nontidal wetlands that were created largely by diking for reclamation are present in the Suisun Marsh and Bay areas.

Saltwater flowing into the Delta was reduced by water management in California's Central Valley. Before the development of California's reservoir system, saltwater intruded far into the upper Delta during summer months. This saltwater intrusion created a seasonally wide range of salinity over a large portion of the estuary. Reservoir operations and other water management practices have reduced saltwater intrusion into the Delta by retaining water during winter and releasing water during summer. Consequently, the area that can support brackish wetlands has been reduced, and the area that can support fresh emergent wetlands has increased. Complex water control systems are now required in Suisun Marsh to preserve the largest single area of saline emergent wetland habitat in California.

Saline emergent wetland area and quality have decreased because of historical conversion to other uses, and reduced land subject to tidal flooding. This habitat has a reduced potential to maintain populations of many native plant and wildlife species. A number of plant species that depend on saline emergent wetlands, including Ferris's milkvetch, soft bird's beak, palmate bird's beak, narrow-leaf gumplant, Suisun Marsh thistle, heartscale, San Joaquin spearscale, crownscale, brittlescale, Delta button celery, and hairy bird's beak, have been given special status because of their reduced populations.

More than 25 species of birds and mammals use saline emergent wetlands in the estuary. Populations of some wildlife species that are heavily dependent on saline emergent wetlands, such as the endangered clapper rail and salt marsh harvest mouse, have been substantially reduced in the Bay-Delta and designated as special-status species. A few wetland-associated species, such as waterfowl and egrets, have adapted to foraging on some types of croplands.

Saline emergent wetland also serves as an important transitional habitat between open water and uplands. Wildlife species that use tidally influenced areas, such as the salt marsh harvest mouse, have adapted to moving during high tides to seasonal wetlands and uplands above the saline emergent wetlands. Loss of adjacent seasonal wetlands and uplands has prevented species associated with these intertidal habitat areas from finding refuge in the higher tidal zone elevations.

Since the turn of the century, an estimated 70,000 acres of saline emergent wetland have been lost in the Suisun Marsh and Bay and the west Delta. The primary factor causing this loss has been wetlands conversion to agricultural and other land uses.

Diking has isolated most of the remaining saline emergent wetlands from tidal flows. Loss of tidal flows into and out of the wetlands has substantially reduced the exchange of nutrients between these wetlands and tidal aquatic communities. Wetlands receiving tidal flows are highly productive, supporting large numbers of important foodweb microorganisms, and maintaining rearing areas for many fish species. Consequently, loss of tidal exchange has greatly reduced the contribution of saline emergent wetlands to the Bay-Delta aquatic ecosystem.

The loss of tidal exchange can also affect the biochemical balance in the soil-water interface. Excessive accumulation of salt in some soils has created conditions unsuitable for plant growth. Agricultural and other land uses have allowed non-native weedy plant species to become established in remaining wetlands. Non-native weeds compete with native plants and change the structure and diversity of the saline emergent plant community from historical conditions.

Tidal exchange is the primary process that supports healthy saline emergent wetlands in the Bay-Delta. Tides flush the wetland system, replacing nutrients and balancing salinity concentrations. Changes in the tidal flux and the accompanying daily and seasonally salinity changes are critical to habitat functioning. Saline emergent wetlands are recognized for their high productivity, which results from the complex interactions of dissolved nutrients with the saline or brackish water. The process of mixing estuarine freshwater with tide-driven saltwater is critical for the biochemical transformations (i.e., carbon and nitrogen cycles) which support the entire estuarine ecosystem.

Human-made stressors negatively affect the health of saline emergent wetlands. Controls placed on seasonal inflow of fresh water to the Delta affect the salinity gradient of the estuary. Land use practices, primarily those associated with agriculture, result in the establishment of weedy plants that displace native, saline-adapted plant species. An associated stressor is the loss of adjacent native upland habitats, which are used by some wildlife species as a temporary refuge when escaping high tides. Collectively, these stressors have substantially reduced the habitat quality of remaining saline emergent wetlands. The combined effect of these actions could eventually be the elimination of much of the remaining habitat.

VISION

The vision for this habitat type is to protect existing saline emergent wetlands from degradation or loss. Wetland habitat will be increased to assist in the recovery of special-status plant, fish, and wildlife populations. Restoration will provide high-quality habitat for other fish and wildlife dependent on the Bay-Delta.

Restoration of saline emergent wetlands would focus on protecting and improving important existing wetlands and restoring wetlands in the Suisun Marsh/North San Francisco Bay Ecological Zones. Restoring saline emergent wetland is dependent on restoring tidal flows, establishing and maintaining healthy estuarine salinity gradients and reestablishing elevation gradients from open water to uplands.

Enhancing and increasing saline emergent wetland habitat would also help to increase water quality. Areas restored to tidal flow will contribute to the aquatic foodweb of the Bay-Delta and provide fish rearing habitat. Restoring saline emergent wetland would improve the ecological value of adjacent associated habitats, including tidal aquatic habitats, and will provide an important transitional zone between open water and uplands.

Other habitat restoration efforts will be directed toward reestablishing native plant species, controlling competitive weedy plants, increasing the quality of adjacent upland habitats to provide refuge for wildlife during high tides, and modifying land use practices that are incompatible with maintaining healthy wetlands. Restoring saline emergent wetlands would be coordinated with restoration of other habitats to increase overall habitat values. For example, saline emergent wetland greatly increases wildlife habitat quality of deep and shallow open-water areas and adjacent grasslands.

These protection and restoration needs could be met by establishing cooperative efforts between government and private agencies. This effort would coordinate implementation of existing restoration strategies and plans; develop and implement alternative land management practices on public lands to improve wetland habitat quality or promote habitat recovery; provide incentives to private landowners to implement desirable land use practices; establish additional incentive programs to encourage landowners to create and maintain saline emergent wetlands; and protect existing habitat areas from future degradation through acquisition of conservation easements or purchase from willing sellers.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore fresh emergent wetland habitat would involve cooperation with other wetland restoration and management programs. These include:

- Suisun Marsh Preservation Agreement,
- Agricultural Stabilization and Conservation Service's Wetland Reserve Program,
- Wildlife Conservation Board's Inland Wetlands Conservation Program,
- restoration programs administered by Ducks Unlimited and the California Waterfowl Association,
- ongoing management of State and federal wildlife refuges and private duck clubs,
- and the San Francisco Bay Wetlands Ecosystem Goals Project.

Proposed ERPP targets may be adjusted to reflect goals identified by the San Francisco Bay Wetlands Ecosystem Goals Project. Agencies or organizations with responsibility or authority for restoring wetland and aquatic habitats will be asked to cooperate. These include:

- U.S. Bureau of Reclamation,
- California Department of Water Resources,
- California Department of Fish and Game,

- U.S. Fish and Wildlife Service,
- and the Delta Protection Commission,

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Saline emergent wetlands are linked to other ecological elements in the Bay. Tidal exchange is an important ecological function that restores the proper salinity and nutrient balance and mixed fresh and estuarine waters.

Saline emergent wetlands are closely linked to open water areas and upland habitats. The value of each habitat is increase by the presence and quality of the adjacent types of habitats. A variety of aquatic and terrestrial fish, wildlife and plant communities depend on healthy saline emergent wetlands. These include numerous plant species and the salt marsh harvest mouse.

Saline emergent wetland are impaired by reduced seasonal inflow of fresh water, land use and loss of upland habitat, and introduction and proliferation of invasive salt marsh plant species.

IMPLEMENTATION OBJECTIVE, TARGETS AND PROGRAMMATIC ACTIONS

The implementation objective for saline emergent wetland habitat is to increase the area of saline emergent wetlands. The increased wetlands area would provide high-quality habitat for waterfowl, shorebirds, and other associated wildlife; provide rearing habitat, foraging habitat, and escape cover for fish; and expand the populations and range of associated special-status and State- and federally listed plant and animal species.

The general target for saline emergent wetland is to restore 7,000 to 11,000 acres in the Suisun Marsh/North San Francisco Bay Ecological Zone.

The following actions would help achieve saline emergent wetlands restoration:

- restore tidal flows to diked wetlands by breaching dikes in suitable areas;
- establish desirable estuarine salinity gradients by managing water diversions and water releases from upstream reservoirs to control seasonal freshwater inflows to the Delta;
- balance seasonal flows from reservoirs for fisheries, water conveyance, flood control, and the needs of other habitats; and
- restore a more natural elevation gradient in wetlands to allow a greater diversity of native saline plant species, including special-status species, that are adapted to different elevations and provide a broader range of habitats for wildlife.

INTRODUCTION

Most fresh emergent wetlands in the Delta occur as narrow, fragmented bands. These fragmented wetlands appear along island levees, channel islands, shorelines and levee blowout ponds. Small areas of nontidal fresh emergent wetlands exist on Delta islands. These Delta island wetlands are primarily associated with agricultural infrastructure (e.g., drainage ditches), levee blowout ponds, and areas managed for wetlands (e.g., duck clubs).

Tidal and nontidal fresh emergent wetland habitats are important habitat areas for fish and wildlife dependent on marshes and tidal shallows and support several special-status plant species. The loss or degradation of historic fresh emergent wetlands has substantially reduced the habitat area available for associated fish and wildlife species. Major factors that limit this resource's contribution to the health of the Bay-Delta are related to adverse effects of wetlands conversion to agricultural, industrial, and urban uses.

RESOURCE DESCRIPTION

Over the past 150 years, more than 300,000 acres of fresh emergent wetlands have been lost in the Sacramento-San Joaquin Delta Ecological Zone. Less than 15,000 acres remain.

Prior to the mid-1800s, extensive areas of fresh emergent habitat occurred throughout the Central Valley, particularly in the Delta. A complex network of rivers, sloughs, and channels connected low islands and basins that supported a diverse and dense variety of freshwater emergent vegetation. This freshwater emergent vegetation supported a diversity of fish and wildlife species and ecological functions.

Vast areas of the Sacramento-San Joaquin Valleys were commonly flooded in winter by a slow-moving blanket of silt-laden water. Flood control activities and land settlements in the late 1800s and early 1900s led to the development of leveed Delta islands. Levees and other land uses led to the loss of fresh emergent wetlands in the Delta. Loss of wetlands has substantially reduced habitat for wetland wildlife species in the Bay-Delta system. Fresh emergent wetland losses have also substantially reduced the area available for the biological conversion of nutrients in the Delta. The Delta contains insufficient wetland area to provide adequate levels of nutrient transformation, which results in lower quality water in San Francisco Bay.

The loss of fresh emergent wetlands has substantially reduced the habitat of several plant and wildlife species. Some species being designated as California or federal special-status and threatened with local extermination. At least eight plant species, Suisun Marsh aster, California hibiscus, bristly sedge, Jepson's tule pea, Mason's lilaeopsis, marsh mudwort, Sanford's arrowplant, and marsh scullcap, are endemic to the Delta. Most of these plants are adapted to a complex tidal cycle and are typically found with more common vegetation such as tule, cattails, common reed, and a great diversity of other herbaceous plant species. Changes in habitat conditions have allowed the invasion of hundreds of non-native weedy plant species. Some of these species, such as water hyacinth, now clog waterways and irrigation ditches and reduce overall habitat quality for native plants and wildlife.

Over 50 species of birds, mammals, reptiles, and amphibians use fresh emergent wetlands in the Delta. Populations of some wildlife species that are closely dependent on fresh emergent wetlands, such as the California black rail, giant garter snake, and western pond turtle, have been substantially reduced in the Delta and designated as special-status species. A few wetland-associated species, such as waterfowl and egrets, have successfully adapted to foraging on some types of Delta croplands converted from historic wetland areas.

Isolating wetlands from tidal flows and removing Delta island fresh emergent wetlands changed the ecological processes that support wetlands. Removing the perennial water and vegetation from the organic soils of Delta islands resulted in soil oxidation and, subsequently, the subsidence of the interior islands. Loss of these tidal flow to islands has reduced habitat for native species of fish, plants, and wildlife; reduced water quality; and decreased the area available for floodwater dispersion and suspended silt deposition.

High water velocities in confined Delta channels continue to erode remaining fresh emergent wetland at a greater rate than habitat formation. Continued erosion reduces the amount of fresh emergent habitat changes the elevation of the land. Elevation affects the types of plant species that can grow depending on a species' ability to tolerate flooding. Flood protection and levee maintenance continue to impair wetland vegetation and prevent the natural reestablishment of fresh emergent wetlands in some locations.

Wind, boat-wake waves, and high water velocities in confined channels actively erode the soil needed to support remnant fresh emergent wetlands. Continued erosion of existing habitat, such as midchannel islands and levees and levee berms, is currently the primary cause of habitat loss in the Delta.

VISION

The vision for this habitat type is to protect existing fresh emergent wetlands from degradation or loss and increase wetland habitat. Achieving this vision will assist in the recovery of special-status plant, fish, and wildlife populations, and provide high-quality habitat for other fish and wildlife dependent on the Bay-Delta.

Restoration of fresh emergent wetlands would focus on protecting and improving important existing wetlands, such as channel islands, and restoring wetlands in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones.

To prevent further loss of existing fresh emergent wetlands erosion rates must be reduced. Inchannel islands and levee berms are of particular concern. Erosion losses could be offset by allowing deposition and wetland establishment. Wetlands erosion could be reduced by reducing boat speeds where wetlands are subject to boat-wake-induced erosion (e.g., Snodgrass Slough). Constructing protective structures around eroding channel islands would weaken wave action (e.g., wave barriers and riprap groins) in a way that retains habitat value for fish and wildlife. Protecting inchannel islands from further erosion and connecting with larger islands would provide greater protection for this unique habitat.

Restoring fresh emergent wetland is dependent on local hydrological conditions (e.g., water depth, water velocity, and wave action); land elevation and slope; and the types and patterns of sediment deposition. The approach to restoring fresh emergent wetlands would include:

- reestablishing the hydraulic, hydrologic, and depositional processes that sustain fresh emergent wetlands and inchannel islands;
- restoring a full spectrum of wetland elevations to allow the establishment of a greater diversity of plant species, including special-status species adapted to different elevations within the tidal or water (nontidal sites) column; and
- providing a broader range of habitats for wildlife.

Restoration of fresh emergent wetlands would be coordinated with restoration of other habitats to increase overall habitat values. Restoration would also include reestablishment of the full diversity of fresh emergent wetland plant associations to ensure that the habitat needs of special-status and other species that are dependent on specific vegetation associations are met.

Protecting and restoring fresh emergent wetlands could be accomplished by implementing elements of existing restoration plans such as Central Valley Habitat Joint Venture; expanding State and federal wildlife areas to create additional wetland complexes; improving management of existing and restoring additional fresh emergent wetlands on private lands; and reestablishing connectivity between the Delta and Delta islands, and between channels with their historic floodplains.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore fresh emergent wetland habitat would involve cooperating with other wetland restoration and management programs. These include:

- Agricultural Stabilization and Conservation Service's Wetland Reserve Program,
- Wildlife Conservation Board's Inland Wetlands Conservation Program,
- restoration programs administered by Ducks Unlimited and the California Waterfowl Association,
- and ongoing management of State and federal wildlife refuges and private duck clubs.

Restoration efforts would be conducted in cooperation with agencies or organizations with responsibility or authority for restoring wetland and aquatic habitats, including:

- California Department of Fish and Game,
- California Department of Water Resources,
- U.S. Fish and Wildlife Service,
- U.S. Army Corps of Engineers,
- and the Delta Protection Commission.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Fresh emergent wetlands are linked to other ecological elements in the ERPP study area. This type of habitat contributes to the aquatic foodweb by supporting nutrient transformation. Fresh emergent wetland also provides habitat for many wildlife and plant species. Some of these are designated California or federal special status species.

Stressors that have reduced the extent of fresh emergent wetlands include flood protection practices, levee construction, and the loss of tidal flow. Increased water velocities in Delta channels causes erosion of wetlands and changes the elevation of the land. Wind and boat wake erosion also contribute to the loss of soil needed to support fresh emergent wetlands in areas where midchannel islands and levee berms are present.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objectives for fresh emergent wetland habitat are to protect and enhance existing wetlands by restoring tidally influenced freshwater emergent wetland in the Delta. This protected wetland would provide high-quality habitat for waterfowl, shorebirds, and other associated wildlife and rearing, foraging, and escape cover for fish. Populations and ranges of special-status and State- and federally listed plant and animal species would be increased.

The overall target for fresh emergent wetlands is to restore or recreate 30,000- to 45,000 acres in the Sacramento-San Joaquin Delta Ecological Zone.

Actions that would help restore fresh emergent wetlands include:

- Setbacks or breaches of island levees to allow water flows to reestablish wetlands with improved but limited ecological functions.

- Increase land elevations in the interior of Delta islands where subsidence has lowered land elevations below tidal emergent wetlands

- Use substrate materials to create levee berms at elevations necessary for fresh emergent vegetation

- Modify, where consistent with flood control objectives, levee vegetation management practices to allow wetland vegetation to naturally reestablish.

- Reintroduce native wetland plants into suitable sites.

These protection and restoration strategies could be implemented by:

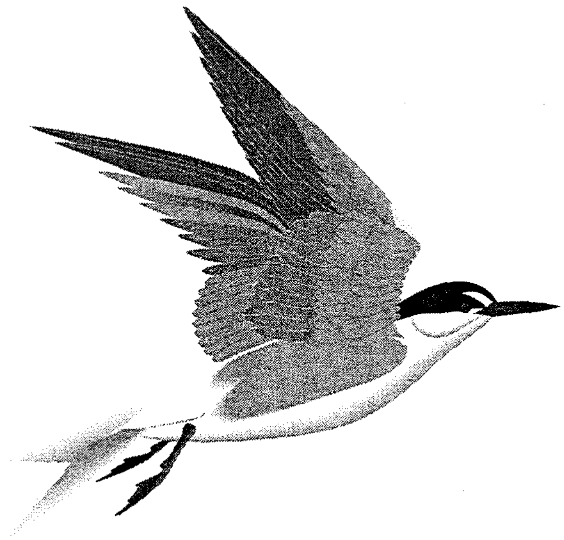
- establishing cooperative efforts between government and private agencies to coordinate the efficiency of implementing existing restoration strategies and plans;

- developing and implementing alternative land management practices on public lands to improve wetland habitat quality or promote habitat recovery, and provide incentives to private landowners to implement desirable land use practices;

- establishing additional incentive programs to encourage landowners to establish and maintain fresh emergent wetlands; and

- protecting existing habitat areas from potential future degradation through acquisition of conservation easements or purchase from willing sellers.

Restoration of stream meander belts and the process of overbank flooding along major tributaries to the Bay-Delta as proposed in the ERPP in other ecological zones will also create the conditions necessary for the natural reestablishment of fresh emergent wetlands elsewhere in the Central Valley.



INTRODUCTION

Bay-Delta seasonal wetlands include vernal pools, wet meadows or pastures, lands that are seasonally flooded, federal refuges, privately owned waterfowl hunting clubs, and private environmental refuge lands, and seasonally flooded areas within a stream course or its floodplain. Historically, seasonal wetlands occurred throughout the Central Valley. Vernal pools and wet meadows are probably best described as specialized components of terrestrial (land-based) habitats. The remaining seasonal wetland types are flooded for periods that are too long to support characteristic upland vegetation.

Seasonal wetlands and aquatic habitats are important habitat areas for many species of fish and wildlife. Loss or degradation of historic seasonal wetlands has substantially reduced the habitat area available for waterfowl, shorebirds, and other wildlife. The loss of seasonal aquatic floodplain habitat has substantially reduced refuge habitat for fish and spawning habitat for the Sacramento splittail. Loss of vernal pools seasonally flooded shallow areas, in particular, has directly resulted in the listing of several species as threatened or endangered under the federal Endangered Species Act.

Major factors that limit the contribution of this habitat type to the health of the Bay-Delta are related to adverse effects of land conversion, and substantial reductions in seasonal overbank flooding.

RESOURCE DESCRIPTION

Vernal pools and wet meadows are associated with soils (basalt flow, claypan, hardpan, volcanic ash-flow, volcanic mudflow, mesa, and plateau) that maintain standing water after winter and spring rains. In some areas of the Central Valley, high spring flows from the rivers and creeks saturate soils. Seasonal wetlands are created when puddles or small ponds form in depressions or standing water remains in low-lying grass fields after river flows recede. Although aquatic plants can establish in areas that are frequently flooded, upland plants cannot survive.

Wet meadows are grassy areas with saturated soils and standing water of varying depths that remain after winter and spring rains end. This habitat is conducive to the production of invertebrates. Invertebrates are the main food source of migrating waterfowl and other birds that periodically forage in these fields. Sandhill cranes forage and roost, and many ducks, geese, and shorebirds also commonly forage in wet meadows throughout the valley. During the dry seasons, many ground-nesting birds, such as pheasants and meadowlarks, nest in meadow grasses. Most wet meadow habitat remaining in the Central Valley, now composed almost entirely of non-native grasses, is used as pasture for livestock.

Vernal pools are often referred to as hog wallows or ponds. These pools are common in grasslands in northern Central Valley where the natural geomorphology remains relatively unchanged. Many State- and federally listed plants (including vernal pool plants), invertebrates, and wildlife, including the western spadefoot toad, California tiger salamander, and various fairy shrimp, are native to or associated with vernal pools. In addition, a variety of birds, including migrating waterfowl, shorebirds, and ground-nesting birds such as meadowlarks, commonly use seasonal wetlands habitat.

Seasonal wetlands play a vital role in the natural succession of plant communities. Seasonal wetlands that maintain surface water for long periods may support cattails, bulrushes, and sedges. Historically, these emergent plant species were probably prevalent along natural stream courses where long-standing water reduced the ability of upland species to establish. These types of wetlands provide the essential building blocks for the future establishment of riparian (streambank) scrub and eventually riparian woodland. Beyond the normal river flows, wetlands probably formed where rains and high flows left areas too wet for terrestrial plants to establish. These wetland areas provided high-quality habitat for waterfowl, other migratory birds, shorebirds, red-legged frogs, giant garter snakes, tricolored blackbirds, and many other wildlife species.

The continued existence of these seasonal wetland types is closely linked to overall ecosystem integrity and health. Although many species that use seasonal wetlands are migratory (e.g., waterfowl and sandhill cranes), many others have evolved (e.g., spadefoot toad, fairy shrimp, and many specialized plants) and adapted to seasonal wetlands.

The extent and quality of seasonal wetlands has declined because of cumulative effects of many factors, including:

- modification of natural geomorphology such as ground leveling for agriculture and development,
- adverse effects of overgrazing,
- contamination from herbicides,
- establishment of non-native species that have an adverse effect on native wetland plants and wildlife,
- flood control and water supply infrastructure that reduces overbank flooding and floodplain size, and
- reduction of the natural underground water table that supported wetlands.

Existing wetland regulations have been in effect for several years in an attempt to prevent the further loss of wetlands. The protected status of wetlands has resulted in an extensive permitting process for construction in wetland areas. Mitigation measures have been developed to offset loss of existing wetlands as a result of construction activities. These efforts have slowed the rate of wetland loss in many areas. Large-scale efforts in areas such as the Suisun Marsh, Grasslands Resource Conservation District, Yolo Bypass, and Butte Sink have been successful in maintaining and restoring seasonal wetlands.

VISION

The vision for seasonal wetlands is to improve the quality of seasonal wetlands by restoring ecosystem processes that sustain them and reduce the effect of stressors that can degrade the quality of seasonal wetlands in order to assist in the recovery of special-status plant and animal populations and provide high-quality habitat for waterfowl, water birds, and other wildlife dependent on the Bay-Delta.

Restoration of seasonal wetlands will focus on protecting and improving important existing wetlands, reestablishing vernal pools within and adjacent to existing ecological reserves, and restoring seasonal wetlands in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones. Seasonal wetland restoration will be coordinated with restoration of other habitats, including shallow-water and riparian woodland and scrub. Restoration would include reestablishment of the full diversity of seasonal wetland plant associations to ensure that the habitat needs of special-status and other species that are dependent on specific vegetation associations are met.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore seasonal wetlands would involve cooperation with other restoration programs, including:

- Upper Sacramento River Fisheries and Riparian Habitat Council,
- Suisun Marsh Protection Plan,
- California Department of Fish and Game wildlife areas,
- U.S. Fish and Wildlife Service refuges,
- Jepson Prairie Preserve,
- Ducks Unlimited Valley Care Program,
- California Waterfowl Association,
- Cache Creek Corridor Restoration Plan,
- The Nature Conservancy,
- Putah Creek South Fork Preserve,
- Woodbridge Ecological Reserve,
- Yolo County Habitat Conservation Plan,
- and Central Valley Habitat Joint Venture.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Seasonal wetlands are linked to other ecosystem elements in the ERPP Study Area. Seasonal wetlands include wet meadows or seasonally flooded pastures, vernal pools, and federal, State, and privately owned refuges and hunting clubs. This habitat supports many species and communities of wildlife and plants.

The health and extent of seasonal wetlands is adversely influenced by land use, herbicide application, proliferation of non-native plant species, flood control practices, and lowering of ground water tables.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objectives for seasonal wetland habitat are to restore and manage this habitat type in the Delta to help restore and maintain the ecological health of the aquatic resources in and dependent on the Delta: restore foodweb and floodplain processes; reduce the effects of contaminants and water management on the Delta's aquatic resources; and provide high-quality foraging and resting habitat for wintering waterfowl, greater sandhill cranes, and migratory and wintering shorebirds.

The general target for seasonal wetland habitat is to restore 59,000 to 89,000 acres in the Sacramento-San Joaquin Delta Ecological Zone and 7,000 acres in the Suisun Marsh/North San Francisco Bay Ecological Zone.

The following actions would help protect and restore seasonal wetlands:

- implement existing restoration plans;

- expand State and federal wildlife areas to create additional wetland complexes;

- improve management of existing wetlands and restore seasonal wetlands on private lands; and

- reconnect channelized streams and rivers with their historic floodplains.

The following actions would help implement protection and restoration strategies:

- establish cooperative efforts between government and private agencies to coordinate the efficiency of implementing existing restoration strategies and plans;

- develop and implement alternative land use practices that will protect grasslands containing vernal pools and wet meadows and allow existing, compatible land uses, such as grazing, to continue;

- develop and implement alternative land management practices on public lands to improve seasonal wetland habitat quality or promote habitat recovery, and provide incentives to private landowners to implement desirable land use practices;

- establish additional incentive programs to encourage landowners to establish and maintain seasonal wetlands;

- protect existing habitat areas from potential future degradation through acquisition of conservation easements or purchase from willing sellers; and

- set back or breach levees and dikes to create the hydrologic conditions necessary for establishing seasonal wetland vegetation.

Restoration of stream meander belts and the process of overbank flooding along major Bay-Delta tributaries proposed in the ERPP in other ecological zones will also create the conditions necessary for the natural reestablishment of seasonal wetlands elsewhere in the Central Valley.

INTRODUCTION

Habitats associated with shorelines of rivers and the Delta include riparian and shaded riverine aquatic habitat. Riparian vegetation includes scrub, woodland, and forest habitats that support a great diversity of wildlife species. Riverine aquatic habitat shaded by riparian vegetation, is important habitat for many species of fish, waterfowl, and wildlife.

Major factors that limit these habitats' contribution to the health of the Bay-Delta include historic riparian vegetation loss or degradation and near-shore aquatic habitat alteration from channelization, stabilization of channel banks with riprap, construction of levees, and control of flows.

Restoring riparian and riverine aquatic habitats will involve reactivating or improving natural physical processes. Natural streamflows, stream meanders, and sediment transport create and sustain these habitats and increase the complexity and structural diversity of the habitat. Natural streamflow patterns help sculpt healthy riparian and riverine aquatic habitats. High winter and spring flows trigger seed dispersal and germination, move sediment, stimulate stream meander, and flood and scour riparian and riverine habitat.

Natural stream channel meanders (often termed "meander belts") provide healthy, high-quality riparian and riverine aquatic habitats. Channelizing rivers (e.g., constructing levees), protecting banks (e.g., adding riprap), and channel dredging hinder natural stream meander and natural river channel morphology.

Natural sources of gravel and other sediments along rivers and floodplains provide materials needed to create and sustain healthy riparian and riverine aquatic habitats. Where improvement to physical processes do not adequately restore riparian and riverine habitats, direct modification may be necessary to restore habitats to their target acreage and quality.

A major increase in floodplain riparian habitat will contribute sediment and nutrient to the rivers and estuaries. It will also improve the foodweb, and provide critical habitat for threatened and endangered terrestrial wildlife species, such as the yellow-billed cuckoo and Swainson's hawk. More extensive and continuous riparian forest canopy on the banks of estuaries and rivers will stabilize channels; help to shape submerged aquatic habitat structure; benefit the aquatic environment by contributing shade, overhead canopy, and instream cover for fish; and reduce river water temperature. More extensive and continuous shoreline vegetation associated with woody debris (branches and root wads) and leaf and insect drop in shallow aquatic habitats will increase the survival and health of juvenile salmonids, resident Delta native fishes, and introduced resident fishes. Achieving this objective will also greatly enhance the scenic quality and recreational experience of our Delta and riverine waterways.

RESOURCE DESCRIPTION

Riparian habitats include the trees, shrubs, vines, herbaceous undergrowth, and organic material and snags along estuaries. These habitat elements combine to create the complex variety of species mixes, age classes, and distribution patterns common to shoreline vegetation. The landforms and changing fluvial streamflow patterns processes that create and interact with riparian vegetation are also an important but often overlooked part of the habitat.

Historically, the Central Valley floor had approximately 922,000 acres of riparian vegetation (Katibah 1984) supported by a watershed of more than 40,000 square miles. Today, approximately 100,000 acres of riparian forest remain. About half of this riparian habitat is in a highly degraded condition, representing a decline of 90% (Katibah 1984). The Sacramento River once supported 500,000 acres of riparian forest; it now supports 10,000-15,000 acres, or just 2-3% of historic levels (McGill 1979, 1987). From about 1850 to the turn of the century, most of the forest was destroyed for fuel as a result of the Gold Rush and river navigation, and by large-scale agricultural clearing.

Additional clearing in early and mid 1900s coincided with the aftermath of flood control reservoir and levee projects. These projects allowed ongoing clearing of floodplain riparian stands for orchards, crops, flood bypasses, levee construction, and urban areas. Similar patterns occurred along the San Joaquin River, which was also greatly affected when major portions of the river were dried up following construction of Friant Dam and other large reservoirs in the San Joaquin Basin. Resulting major changes in river flow conditions and sediment deposits triggered channel instability, and downcutting of rivers and streams that caused additional riparian and riverine habitat loss and fragmentation.

Riverine aquatic habitats comprise the relatively shallow submerged and seasonally flooded areas in estuary and river channel beds. Channel beds contain gravel beds, bars, and riffles; transient sandy shoals; waterlogged woody debris piles; and the shaded riverine aquatic habitat zone. The shaded riverine aquatic habitat is located where the river meets the riparian canopy. Riverine aquatic zones provide spawning substrate, rearing and escape cover, feeding sites, and refuge from turbulent stormflows for fish and other aquatic organisms.

The condition of riverine aquatic and nearshore habitats is not well documented for most of Central Valley and Delta estuaries, rivers, and streams. The condition of these habitats has been degraded by channel straightening; channel incising; channel dredging and clearing; instream gravel mining; riparian zone grazing; flow modifications; removal and fragmentation of shoreline riparian vegetation; and the loss of sediment, bedload, and woody debris from watershed sources upstream of dams.

Riparian and riverine aquatic habitats are created and sustained by natural fluvial processes associated with rivers. Fluvial dynamics are affected by the presence and pattern of riparian vegetation. Vegetation patterns define and contribute to riparian and riverine aquatic ecosystem structure and functions.

In general, riparian and riverine aquatic habitats are healthiest where ecosystem processes are in the most unaffected natural state. These sites are also the most resilient to human and natural disturbance. Ecosystem processes that are integral components of riparian and riverine aquatic habitats are described in greater detail in the ecosystem restoration visions for stream meander corridors, floodplains, natural geomorphology and sediment supply.

Sediment transport, deposition, and scour support, succession, and regeneration of riparian vegetation. These secondary processes require frequent high flow events in winter and spring. These frequent high flows redistribute sediment and bedload. After new vegetation is established on sediment bars and freshly deposited floodplains, the primary physical factors that sustain riparian vegetation are adequate streamflow, winter inundation of the floodplain, and shallow groundwater during the dry season.

Sediment transport and deposition, are also the processes that create and replenish riverine aquatic habitats. A high-quality aquatic habitat requires a continuous supply of sediment. Riverflows must periodically be high enough and of sufficient duration to move streambed materials.

Sediment deposits are shaped, in part, by riparian vegetation. Riparian vegetation resists flow and causes fine sediment to aggrade within the dense stems. Riparian vegetation also redirects flows and causes the channel water to scour the bed. Scouring action forms pools, riffles, and bar patterns. Away from high-energy estuary channels, tidal mudflats form in broad, low-velocity areas when shoals of organic-rich fines are deposited.

Riparian vegetation serves many important ecological functions. Riparian vegetation absorbs nutrients and produces primary (plant) and secondary (invertebrate) biomass at very high rates. This biomass feeds numerous fish and wildlife species. Birds and small mammals nest and take cover in the protective canopy foliage of trees. Trees also shade and cool floodplains and channels. Channel velocities are slowed by riparian foliage, allowing sediment to settle and create new landforms. Riparian foliage also stabilizes channels and banks, thereby rendering the characteristic geomorphology of estuaries, rivers, and streams.

Primary stressors affecting riparian habitats include:

- channel straightening and clearing;
- levee construction and bank hardening to protect bridge abutments and diversion structures (e.g., with riprap);
- instream gravel mining and riparian zone grazing;
- flow modifications affecting sediment transport and spring germination;
- removal, burning, and fragmentation of mature riparian vegetation; and
- loss of sediment and bedload from watershed sources upstream of dams.

Other stressors increasing in importance and magnitude include:

- displacement by invasive non-native trees and shrubs (e.g., tamarisk and giant reed),
- new expansion of orchards and vineyards into the riparian floodplain,
- human-set fires along river parkways,
- unusually high summer stage in rivers that supply increasing demand for downstream water diversions,
- groundwater lowered below the root zone, and
- expanded clearing of channel vegetation in response to recent flood events that called into question the capacity of levee-confined rivers and streams.

Most stressors have an indirect but lasting effect on the physical structure and postdisturbance recovery of streambed habitat. Collectively, these stressors have substantially reduced the quality and resilience of riverine aquatic habitats, thereby diminishing their effectiveness in providing for the life cycle requirements of fishes of the Delta and Sacramento and San Joaquin Rivers and their tributaries.

VISION

The vision for riparian and riverine aquatic habitats is to protect and increase their area and quality. Achieving this vision will assist in the recovery of special-status fish and wildlife populations and provide high-quality habitat for other fish and wildlife dependent on the Bay-Delta. The vision includes restoring native riparian communities ranging from valley oak woodland associated with higher, less frequently inundated floodplain elevations to willow scrub associated with low, frequently inundated floodplain elevation sites such as streambanks, point bars, and inchannel bars.

The simple preservation of remaining natural riparian areas and riverine aquatic zones will not ensure the diversity,, and resilience of these habitats. Preservation alone is not adequate because of the scarcity, degradation, and fragmentation of existing river and estuary systems. Most riparian restoration projects in the Central Valley have been implemented on a relatively small scale, primarily as mitigation for project impacts or infill of existing protected preserves. The National Research Council (1992) has recommended a national strategy for restoring rivers and aquatic ecosystems through integrated restoration of large landscape units.

If the floodplain, meander width, sediment supply, and natural spring flows are in place, the river will respond by creating natural landforms. These landforms will support self-sustaining vegetation communities and streambed habitats. Even partial restoration or simulation of natural physical processes and floodplains will amplify ecosystem characteristics and resultant habitat quality. Rivers and Delta estuaries where natural fluvial processes and landforms are relatively intact need to be identified and highlighted as potential reserves of riparian and riverine habitat. Complete restoration on many segments may be limited by unalterable levee confinement and bridge crossings.

Restoring riparian and riverine aquatic habitat depends on recovery or simulation of natural fluvial processes and landforms. Revegetating and artificially altering stream channels will be considered only where overwhelming limitations prevent natural recovery of these physical processes and ecosystem functions.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to achieve the vision for riparian and riverine aquatic habitats may involve coordination with other programs. These include:

- U.S. Army Corps of Engineers' proposed reevaluation of the Sacramento River flood control project and ongoing bank protection project, including more comprehensive floodplain management and river ecosystem restoration opportunities;
- SB1086 Advisory Council efforts and river corridor management plan for the Sacramento River;
- the San Joaquin River Parkway and Management plans;
- proposed riparian habitat restoration and floodplain management and riparian restoration studies for the San Joaquin River, including potential new flood bypass systems and expanded river floodplains on lands recently acquired by State and federal agencies and land trusts;
- ongoing Sacramento Valley conservation planning by The Nature Conservancy and other private nonprofit conservation organizations;
- expansion plans and conservation easements underway for the Sacramento River National Wildlife Refuge and California Department of Fish and Game's Sacramento River Wildlife Management Area;
- ongoing coordination efforts and programs of the Wildlife Conservation Board, including the Riparian Habitat Joint Venture;
- all county-sponsored instream mining and reclamation ordinances and river and stream management plans;

- and the California Department of Conservation reclamation planning assistance programs under the Surface Mining and Reclamation Act.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Riparian and riverine aquatic habitats are closely linked to the ecological health of many ERPP Ecological Zones and Units. This type of habitat is important to many fish, wildlife, and plants species and communities. It is adversely affected by many stressors that include levee construction, gravel mining, flow patterns, fragmentation of existing stands of riparian vegetation, competition and displacement by non-native plant species, land use and conversions, fires, lowered groundwater levels, and removal to increase flood control channel capacity.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for riparian and riverine aquatic habitats is to restore riparian scrub, woodland, and forest habitat along largely nonvegetated, riprapped banks of Delta island levees, the Sacramento and San Joaquin Rivers, and their major tributaries. Restored riparian habitat would provide shaded riverine aquatic cover for fish species, associated special-status plant and animal species, and other wildlife.

General restoration targets for riparian and riverine aquatic habitat include acquisition of easements or in-fee title to 16,000 to 24,000 acres of riparian lands in the stream meander zone along the Sacramento River between Red Bluff and Colusa and the acquisition or protection of riparian corridors along most of the streams and rivers throughout the ERPP Study Area.

Recovery and simulation of natural fluvial processes and landforms will be accomplished using the following integrated steps:

- locating setback levees to expand potential riparian floodplain;
- expanding the storage, detention, and bypass capacity of the Sacramento and San Joaquin River flood control project to allow natural expansion of riparian vegetation within levees and the Sutter and Yolo Bypasses; and
- designating, acquiring title or easements for, and deliberately managing river corridor meander zones on appropriate rivers and stream throughout the Central Valley.

The following actions would restore or enhance sediment supply to rivers and streams:

- reduce bank hardening by creating meander zones and widening floodplains;
- analyze alternative approaches for water diversions and associated intake and screening facilities on the mainstem river to avoid hardening the bank in some sections of the river;
- remove small, nonessential dams on gravel-rich streams;
- eliminate mining in streams and on low floodplains near channels; and
- widen bridges to broaden out-of-bank flow and eliminate the need to riprap vulnerable bridge abutments.
- breach or remove nonessential levees restricting former tidelands [that] would capture sediment needed to create tidal mudflats and estuary landforms.

These measures will significantly increase the extent and distribution of shallow-water and nearshore habitats. These habitats are productive generators of the Delta foodweb and provide essential new rearing habitat for juvenile Delta and anadromous fish. Where Delta land elevations are suitable, levee systems can be set back or altered to allow out-of-bank shallow flooding during high flood stage. Floodplain inundation will also provide additional flood storage and moderation of peak flows to decrease the risk of flooding elsewhere in the Delta. Foodweb support, spawning and rearing habitat for native fish (e.g., splittail), would be further enhanced by altering levees.

Opportunities for reducing riparian habitat stressors include:

- phasing out instream gravel mining;
- designating and acquiring "stream erosion zones" to reduce the use of bank riprap and allow greater natural recolonization;
- designing biotechnical slope protection measures that allow riparian vegetation to be established within levees;
- phasing out or reducing livestock grazing in riparian zones;
- establishing conservation easements for purchase of land or using other incentives to reduce or eliminate cropland conversion of riparian forest;
- eliminating or modifying programs which remove large woody debris from stream channels and rivers;
- identifying levee-confined channels and banks where routine vegetation removal by local reclamation districts can be safely discontinued; and
- establishing weed control programs to suppress the expansion of tamarisk, giant reed, locust, and other invasive non-native plants degrading habitat quality and native flora.

Opportunities for reducing stressors affecting riverine aquatic habitat include:

- phasing out instream gravel mining (especially downstream of dams and on streams that support salmon and steelhead spawning);
- designating and acquiring "stream erosion zones" to reduce the use of bank riprap and allow natural meander patterns;
- designing slope protection measures that allow shoreline riparian vegetation to be established within levees;
- phasing out or reducing livestock grazing in riparian and aquatic zones (especially on tributary streams that support salmon and steelhead spawning); and
- identifying levee-confined channels and banks where routine channel clearing and grading can be safely discontinued.

Reservoir operations will be evaluated to determine whether winter and spring releases can be augmented with flood simulation spikes every 1-10 years. Simulated flood spikes would mobilize bed and bank deposits to redistribute, sort, and clean spawning gravels and scour deep pools between riffles.

Restoring riparian and riverine aquatic habitat should be accomplished by eliminating the stressors and recovering or simulating the physical processes and fluvial landforms described above. Habitat restored in this way will be more resilient to future disturbances; require little or no long-term maintenance; be self-sustaining; and be more compatible with flood control requirements.

However, habitat fragmentation and severe limitations of the physical environment will not allow ecosystem processes and functions to fully recover on many segments of valley streams and

Delta estuaries. In these situations, some large-scale stream channel sculpting, gravel additions, and riparian replanting may be necessary. For example, the lower Sacramento River has abandoned river floodplains and sediment is in short supply. Naturally reactivating these habitats would be nearly impossible. Restoring these habitats would require human intervention. Revegetation projects should be contemplated only where native trees and grasses may no longer germinate naturally but have a high probability of unaided survival and vigorous growth following 1-5 years of artificial irrigation.

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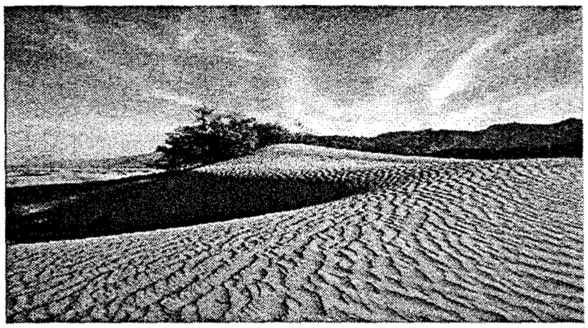


INTRODUCTION

Inland dune scrub is associated with inland sand dunes and is limited in the ERPP focus area to the vicinity of the Antioch Dunes National Wildlife Refuge. This habitat area supports two plant and one butterfly species listed as endangered under the federal Endangered Species Act. Major factors that limit this resource's contribution to the health of the Delta are related to adverse effects of sand mining, dune conversion to other land uses, dune stabilization, and land use practices that maintain the dominance of non-native plants.

RESOURCE DESCRIPTION

Historic dunes within the Sacramento-San Joaquin Delta Ecological Zone may have covered 15,560 acres, based on soil surveys, including 8,510 acres of Delhi series, 5,810 acres of Piper series in Contra Costa County, and 1,300 acres of Tinnin series in Sacramento County. The Delhi series was a large area of dunes in the Antioch-Oakley area, of which the Antioch Dunes National Wildlife Refuge is a tiny remnant. The Piper series were small areas of remnant dunes within the organic soils of the Delta marshes, remnants of larger areas of dunes that existed prior to the rise in sea level at the end of the last ice age. The Tinnin series were small isolated dunes on the eastern edge of the Delta.

Remaining habitat areas are being protected. Recent land-use changes help this habitat support several special-status plant and wildlife species. Most protected inland dune scrub is located within the Antioch Dunes National Wildlife Refuge and Brannan Island State Park. Most of the inland dune scrub habitat outside these two areas are protected to various degrees.

Two special-status plant species, the Antioch Dunes evening primrose and the Antioch Dunes wallflower, are found with inland dune scrub. The Lange's metalmark, a butterfly listed as endangered under the federal Endangered Species Act (ESA), is known only from the Antioch Dunes, where it feeds on naked buckwheat. The low nutrient conditions of the soils and natural instability of dune sands limit the amount of vegetation that establishes on the inland dunes. The dunes represent a localized habitat that does not support other types of upland vegetation.

As in other dune ecosystems, such as coastal dunes and desert sand dunes, wind is the major process that shapes dunes and dune structures. The presence of the wind-modified, river-deposited sands, in combination with the Delta wind patterns, maintain a natural disturbance threshold that favors the establishment of the plant species that are characteristic of dunes and prevents the establishment of species less tolerant of these conditions.

Direct and indirect disturbances are reducing the extent and health of inland dune scrub habitat and its associated plants and animals. Sand mining directly removes habitat. Urban development has moved onto historical dune habitat and changed wind-flow patterns. Excessive foot traffic, off road vehicle traffic, and grazing disturb dune surfaces, which makes dunes more susceptible to erosion. Application of herbicides, pesticides, and fertilizers change ecological processes that may encourage or support non-native species. Structures or activities that reduce or accelerate winds, wind-disturbances, or barriers to wind-driven sand movement, disrupt the processes that sustain dunes. Wind patterns blow river-deposited sand into shifting dunes. Shifting sand offers little stability for establishing plant root systems. Plant species characteristic of dunes survive within a disturbance threshold. Direct disturbances inhibit the ability of dune-associated plants to establish and result in loss of plant vigor or mortality. Sand movement barriers create conditions unfavorable for establishing native dune vegetation. These types of disturbances create site conditions conducive to establishing invasive weedy plants. Non-native weeds compete with native dune plants and reduce overall habitat quality. Continued disturbance of potentially restorable adjacent habitat could interfere with protecting and restoring additional areas of high-quality habitat by affecting dune structure and destroying buckwheat, Antioch evening primrose, and Antioch Dunes wallflower plants.

VISION

The vision for inland dune scrub habitat is to protect and enhance existing areas and restore former habitat areas. Achieving this vision will provide high-quality habitat for associated special-status plant and animal populations.

Restoration of inland dune scrub would focus on protecting and improving important existing habitat areas. Historic inland dunes adjacent to existing ecological reserves in the Sacramento-San Joaquin Delta Ecological Zone would be reestablished. Protecting and restoring inland dune scrub habitat would begin by identifying areas that are not currently managed for their resource values. Appropriate methods to protect and restore identified areas would be developed. Protected habitat areas would be evaluated to determine effective restoration management practices to increase habitat value. The results of these evaluations would determine how habitat would be protected and restored.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore inland dune habitats will involve cooperation with programs managed by the Antioch Dunes National Wildlife Refuge. Cooperation from agencies with responsibility or authority for restoring inland dune habitat will be solicited. These include:

- California Department of Fish and Game,
- U.S. Fish and Wildlife Service,
- U.S. Army Corps of Engineers,
- and the Delta Protection Commission,

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Inland dune scrub habitat is limited to the area near the Antioch Dunes Ecological Reserve, Brannan Island State Park and a few other localities. This type of habitat is important for two plant and one butterfly species listed as endangered under the federal Endangered Species Act.

It is adversely affected by human caused actions that contribute to erosion and spread of non-native species. One important linkage in maintaining this habitat is maintenance of river flows which deposit sediments including sand which feed the dune formation process.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

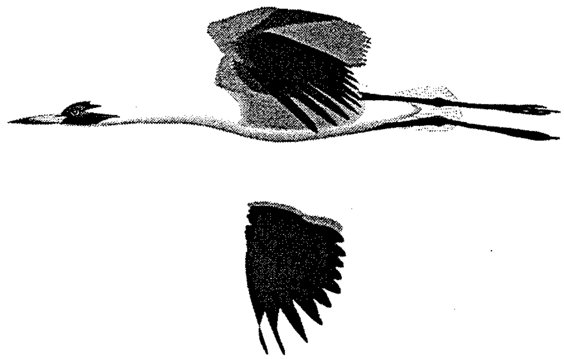
The implementation objective for inland dune scrub habitat is to improve low- to moderate-quality Delta inland dune habitat to support special-status plant and animal species and other associated wildlife populations.

General restoration targets for inland dune scrub habitat are directed at protecting and restoring 50 to 100 acres of low- to moderate-quality Antioch inland dune scrub habitat within or adjacent to existing ecological preserves in the Central and West Delta Ecological Unit.

Managing protected areas could include reducing disturbance of dunes and dune vegetation. This could be accomplished by reducing vehicle and pedestrian access to dune areas. Protective structures, such as small boardwalks could be built. These actions would reduce habitat disturbance while maintaining recreational access. The following actions would help restore inland dunes:

- remove barriers to wind-driven sand-dune movement to increase the area that would be available for natural expansion of the sand-dune base;
- import sands from areas being developed or clean sand dredged from Bay-Delta channels to increase restoration potential and dune area;
- control non-native weeds to recreate conditions suitable to reestablishing native dune plants; and
- reduce the use of herbicides, pesticides, and fertilizers that adversely effect native dune vegetation and animals.

Dune habitat protection and restoration strategies could be implemented through cooperative efforts with existing ecological reserves. Restoration efforts should focus on implementing existing protection and restoration programs, establishing cooperative agreements with land management agencies, and establishing conservation easements or purchasing land from willing sellers.



INTRODUCTION

Perennial grasslands provide important breeding and foraging habitat areas for many wildlife species and support several special-status plant species. Perennial grassland was historically common throughout the Central Valley. Most perennial grassland has been lost or converted into annual grassland. Major factors that limit this resource's contribution to the health of the Bay-Delta are related to the adverse effects of grasslands conversion for agricultural, urban, and industrial uses, and continuing land use practices that maintain non-native annual grasses dominance in historic perennial grassland habitat.

RESOURCE DESCRIPTION

Perennial grassland provides habitat for many plant and wildlife populations and are important for maintenance of vernal pools and their associated plant and animal species.

In addition to supporting vernal pools, perennial grasslands provide valuable habitat for many wildlife species. Common grassland species include deer, San Joaquin kit fox, ground squirrels, kangaroo rats, and blunt-nosed leopard lizards, and nesting waterfowl. Where grassland still occurs, it also provides an extremely valuable transition zone and support area for adjacent habitats.

Perennial grasslands and associated vernal pools historically were present at drier, higher elevations in the Delta. Grasslands developed adjacent to wetland and riparian habitats that occupied wetter, lower elevation. Much of the perennial grasslands have been converted for other uses. Most remaining grasslands are now dominated by non-native annual grasses. Annual grasses out competed and replaced perennial bunch grasses over most of the Central Valley.

Extent and health of perennial grasslands in the Bay-Delta estuary are declining. Large areas of historic perennial grassland has been converted for agriculture, urban, and industrial uses. Remaining grasslands have been invaded by non-native annul grass. Many of the annual grass species out-compete native grasses. Fire-resistant, non-native species have been given an additional competitive edge from current fire suppression techniques. For example, native bunch grasses are fire resistant and adapted to relatively frequent fires because their perennating buds are near the ground and protected by the rest of the plant. Present fire suppression activities may favor non-native annuals which, because of infrequent catastrophic fires, destroy the bunch grasses when very hot fires burn the thatch which has built up over time. Fires promote plant succession and have aided in the intrusion of non-native fire-tolerant plants; and continuation of land use practices that maintain the dominance of non-native annual grasses.

VISION

The vision for perennial grassland is to protect and improve existing perennial grasslands and increase grassland area. This vision is a component of restoring wetland and riparian habitats. Achieving this vision will provide high-quality habitat for special-status plant and wildlife populations and other wildlife dependent on the Bay-Delta.

Restoration of perennial grassland would focus on reestablishing historic grasslands and protecting and improving important existing grassland areas in the Sacramento-San Joaquin Delta, Suisun Marsh/North San Francisco Bay, and Yolo Basin Ecological Zones. Grasslands would be restored as a component of wetland and riparian habitat restoration. Combining these restoration efforts increases overall habitat value for species that require multiple habitats. The proximity of habitats to each other (e.g., grasslands adjacent to wetlands provides nesting habitat for several species of ducks and refuge habitat for small mammals during flooding) and provides a protecting buffer from potential adverse effects of adjacent land uses.

Reducing land use changes and the introduction of non-native species will decrease the major stressors affecting perennial grasslands and vernal pools. The promotion of fire as a natural method for succession would aid in managing fire-sensitive non-native plants. Alternatives to the use of herbicides and other contaminants to control vegetation should be encouraged to promote more natural revegetation.

Increasing the quantity and quality of grasslands habitat conditions would help increase special-status plant and wildlife populations. Habitat improvements would also maintain or increase populations of other species that are dependent on grasslands in the estuary.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Protecting and restoring perennial grasslands are objectives of agencies and organizations that operate many protected habitat areas. These include:

- Cosumnes River Preserve,
- Grizzly Slough Wildlife Area,
- Jepson Prairie Preserve,
- Putah Creek South Fork Preserve,
- Stone Lakes National Wildlife Refuge,
- and Woodbridge Ecological Reserve.

Restoring perennial grassland is also an objective of the Cache Creek Corridor Restoration Plan and Yolo County Habitat Conservation Plan.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Perennial grasslands are an important component of the Bay-Delta ecosystem and provide habitat for many plant and wildlife populations. Common species dependent on perennial grasslands include deer, San Joaquin kit fox, blunt-nosed leopard lizards, kangaroo rats and nesting waterfowl. Grassland also provide an important transition habitat between adjacent habitat areas. In addition, health grasslands provide contributions to flood control function by slowing and extending storm events and by reducing erosion.

This type of habitat is adversely affected by land use, land conversion, and proliferation of non-native plant and grass species. Control of exotic plant species is a significant stressor and control programs need to be developed for protecting and restoring perennial grasslands.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective is to preserve and restore perennial grassland habitat in conjunction with restoration of wetland and riparian habitats in order to provide high-quality habitat conditions for associated special-status plant and wildlife populations.

The general target for perennial grassland is to protect and restore 4,000-6,000 acres in the Sacramento-San Joaquin Delta Ecological Zone and 1,000 acres in the Suisun Marsh/North San Francisco Bay Ecological Zone.

Restoring, protecting, and improving grasslands could be achieved through:

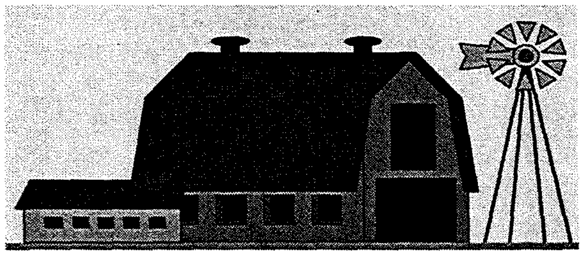
- purchasing land or conservation easements or from willing landowners to protect important existing habitat areas from potential future degradation,

- establishing incentive programs to encourage landowners to establish and maintain perennial grasslands,

- implementing an intensive management program to control non-native vegetation and enhance native grasses and other plant species, and

- developing and implementing alternatives to land management practices on public lands that continue to degrade habitat quality or inhibit habitat recovery.

Restoring other ecological processes and habitats proposed by the Ecosystem Restoration Program Plan (ERPP) would also create opportunities for the managed reestablishment of grasslands elsewhere in the Central Valley.



INTRODUCTION

Following extensive native habitats loss in the Central Valley to agricultural and urban lands, some wildlife species have adapted to the artificial wetland and upland environments created by some agricultural practices. Once adapted, species became dependent on these agricultural areas to sustain their populations.

A major factor that limits this resource's contribution to the health of the Bay-Delta is related to adverse effects of some agricultural practices. Clean farming practices reduce the availability and quantity of forage and fence-line vegetation. Converting production from crops that provide relatively high-values for wildlife to relatively low-value crop types, displaces or insufficiently supports species that have adapted to the habitat. Converting agricultural lands for urban or industrial uses, also reduces or eliminates available habitat.

RESOURCE DESCRIPTION

Agricultural lands are located throughout the Central Valley. These lands comprise many different types of agricultural land uses ranging from non-irrigated grazing land to drip-irrigated vineyard. The type of crops grown on any particular parcel are usually dictated by soil type, topography, and availability of water. Intensively managed agricultural lands or croplands are located on flat or slightly rolling terrain. Flat cropland is usually the product of extensive surveying and laser land-leveling activities. Flat croplands provide more efficient use of water, less soil erosion, and higher crop yields. A variety of fragmented habitats that support various resident and migratory wildlife species are closely associated with these agricultural lands and includes naturally occurring wetland types (creeks, vernal pools, and gullies).

Agricultural lands being managed for certain crops and following certain agricultural practices create wetland-like benefits for certain wildlife. These lands can provide significant habitat for some wildlife species. Crop type and cultivation practices determine the quality of habitats. For example, rice lands support millions of wintering waterfowl using the Central Valley. Lands where wheat and corn have been harvested, particularly if they have been shallowly flooded after harvest, also support large populations of wintering waterfowl and the State-listed greater sandhill crane.

Major stressors that determine the wildlife values provided by agricultural lands include activities such as water quantity and quality management, crop type conversion from relatively high-wildlife-value crops to relatively low-wildlife-value crops (e.g., conversion from pastureland rowcrops to vineyards), the use of "clean farming techniques", deep postharvest discing, practices that reduce crop and grain residue within the field, cropland management with varied pesticide application, and the timing of these activities. Implementing appropriate land use management techniques accompanied by reimbursement programs to the agricultural stakeholder can reduce the adverse impacts of stressors on diverse agricultural habitat.

VISION

The vision for agricultural lands is to improve associated wildlife habitat values to support special-status wildlife populations and other wildlife dependent on the Bay-Delta.

Protecting and enhancing agricultural lands for wildlife would focus on encouraging production of crop types that provide high wildlife habitat value, agricultural land and water management practices that increase wildlife habitat value, and discouraging development of ecologically important agricultural lands for urban or industrial uses in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones.

Vegetation management of agricultural lands could provide wildlife habitat at many locations, including rice checks, irrigation ditches, lowlands, ponds, fallow lands, fence rows, and other areas unsuitable for agricultural land use. Agricultural crop types that present excellent opportunities for enhancement include rice, alfalfa and pasture, corn and grain, and certain rowcrops. Enhancing agricultural lands adjacent to existing wildlife habitat areas, such as refuges, would be particularly beneficial. The value of enhanced land could be increased if nearby nonfarmed or fallow lands were managed to provide other habitats required by wildlife that use agricultural lands.

In some situations, altering common management practices can greatly increase wildlife habitat value with little or no change in crop production.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Numerous agricultural habitat improvement projects involving a number of project proponents are proposed and in various stages of development throughout the ecological zones. Some of the more notable projects are:

- Stones Lakes National Wildlife Refuge, Cosumnes River Preserve, and
- Yolo Bypass Wildlife Management Area.

There are also many voluntary landowner incentive programs that involve various agricultural habitat improvements in the ecological zones. These include:

- Wetland Reserve Program,
- Agricultural Conservation Program,
- Water Bank Program,
- Partners for Wildlife,
- California Waterfowl Habitat Program,
- Inland Wetland Conservation Program,
- Conservation Reserve Program,
- Agricultural-Wildlife Incentive Program (CVPIA), and
- Permanent Wetland Easement Program.

Governmental and private agencies and agricultural stakeholders involved in current agricultural land enhancement and management include:

- California Department of Fish and Game,
- California Department of Water Resources,
- California Department of Transportation,
- U.S. Fish and Wildlife Service,
- U.S. Bureau of Land Management,
- U.S. Bureau of Reclamation,

- U.S. Natural Resources Conservation Service,
- Ducks Unlimited
- Valley Care (Ducks Unlimited),
- Central Valley Habitat Joint Venture,
- The Nature Conservancy,
- resource conservation districts,
- farm bureaus,
- county agricultural commissions,
- and various county land planning agencies.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Agricultural lands are an important habitat for many migratory wildlife species, particularly for wintering waterfowl and the State-listed greater sandhill crane.

Wildlife values of agricultural lands are adversely affected by water quantity and quality, type of agricultural crop produced, farming techniques, and application of pesticides.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for agricultural lands is to co-manage agricultural upland and wetland habitat to provide wildlife forage and resting area habitat for wintering and migrating waterfowl, shorebirds, and other associated wildlife in the Delta.

The general target for agricultural land is to cooperatively manage 40,000-75,000 acres for agriculture and wildlife in the Sacramento-San Joaquin Delta Ecological Zone.

Actions that would help increase wildlife quality include:

- deferring fall tillage until later in the year can increase the quantity of forage on cornfields for waterfowl and greater sandhill cranes,
- shallow flooding of seasonal croplands in fall/winter can greatly increase the availability of forage for wintering waterfowl
- retaining a percentage of the unharvested crop in the agricultural field would enhance the value of flooding.

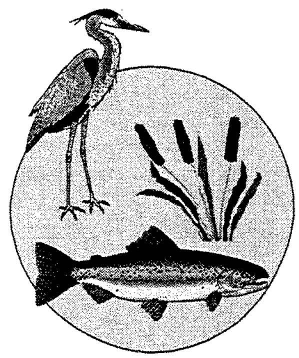
Incidental benefits to agricultural stakeholders from improving conditions for wildlife would be:

- groundwater recharge to aquifers used for summer irrigation,
- leaching salts from soils,
- biological decomposition of crop residue,
- reduction in soil erosion, and
- create an opportunity for cash income from hunting and increase esthetic values, both of which may increase property values.

Protecting and enhancing agricultural lands would be achieved through participation and cooperation with agricultural stakeholders, including farmers, ranchers, and other landowners and lessees. Mechanisms to protect and enhance agricultural lands include various multi year agreements, conservation easements, and purchases through specific payment programs between resource agencies and willing participants.

INTRODUCTION

This section presents visions for species and species group ecosystem elements. Species and species groups included occur in or are dependent on the Bay-Delta. Many of these species are listed or proposed for listing as threatened or endangered under the California or federal Endangered Species Acts (ESAs), designated as a species of special concern by the California Department of Fish and Game (DFG), or the U.S. Fish and Wildlife Service (USFWS). Visions were also created for important recreational or commercial species. Important prey or foodweb species are also included. Table 8 identifies important fish and wildlife species and species groups and associated implementation objectives. Table 9 presents the basis for selecting each habitat type as an ecosystem element.



Visions describe what the Ecosystem Restoration Program hopes to achieve for each species and species group, how the vision is to be achieved through restoring ecological processes and habitats and reducing the effects of stressors. Proposed population targets and programmatic actions to help achieve targets are also included in visions. "Ecosystem Restoration Program Plan, Volume II: Ecological Zone Visions" contains more specific objectives, targets, and programmatic actions for each species by specific geographic zone. Table 10 identifies which ecological zone(s) in which the species are treated in more detail.

TABLE 8. SPECIES AND SPECIES GROUPS ECOSYSTEM ELEMENTS AND ERPP IMPLEMENTATION OBJECTIVES

Species Type	Implementation Objectives
Delta Smelt	ensure the recovery of this species, which is State- and federally listed as threatened in order to contribute to overall species diversity and reduce conflict between the need for its protection and other beneficial uses of water in the Bay-Delta.
Longfin Smelt	ensure the recovery of this species of special concern in order to contribute to overall species diversity and reduce conflict between the need for its protection and other beneficial uses of water in the Bay-Delta.
Splittail	ensure the recovery of this species, which is proposed for listing under the federal Endangered Species Act (ESA) in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of water in the Bay-Delta.

Species Type	Implementation Objectives
White and Green Sturgeon	restore the distribution and abundance of the white sturgeon to historical levels to support a sport fishery, and ensure the recovery of the green sturgeon, a California Department of Fish and Game species of special concern in order to contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of water in the Bay-Delta.
Chinook Salmon	ensure the recovery of the Sacramento winter-run chinook salmon, a species listed as endangered under the federal and California Endangered Species Acts (ESAs) in order to ensure overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of water in the Bay-Delta. The objective is also to ensure the restoration of Sacramento fall-run, spring-run, late-fall-run, and San Joaquin fall-run chinook salmon to support sport and viable commercial fisheries.
Steelhead Trout	ensure the recovery of this species, which is proposed for listing under the federal Endangered Species Act (ESA), to sufficient population size to support inland recreational fishing and fully use existing and restored habitat areas in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of water in the Bay-Delta.
Striped Bass	restore its population levels to those of the 1960s to contribute to a recreational fishery in the Bay-Delta in order to reduce conflict between the need for its protection and other beneficial uses of water in the Bay-Delta.
American Shad	maintain naturally spawning populations that support sport fisheries similar to fisheries that existed in the 1960s and 1970s in order to contribute to the recreational use of the Bay-Delta.
Resident Fish Species	maintain and restore the distribution and abundance of resident native fish species, such as Sacramento blackfish, hardhead, tule perch, and Sacramento perch, and non-native species, such as white catfish, largemouth bass, and threadfin shad, in order to support a sport fishery and healthy forage populations.
Marine/Estuarine Fishes and Large Invertebrates	maintain, improve, and restore populations of these species to levels that existed in the early 1980s in order to contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of water in the Bay-Delta.
Bay-Delta Aquatic Foodweb Organisms	restore the estuary's once-productive food base of aquatic algae, organic matter, microbes, and zooplankton.

Species Type	Implementation Objectives
Special Status Plant Species	assist in their recovery, ensure the protection of habitats for existing populations, establish new populations, and ensure the long-term viability of the species.
Plant Community Groups	maintain habitat of existing population and ensure the long-term viability of certain plant communities.
Western Spadefoot and California Tiger Salamander	assist in the recovery of both species of special concern in the Bay-Delta in order to contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of water in the Bay-Delta.
California Red-Legged Frog	assist in the recovery of this federally listed threatened species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
Giant Garter Snake and Western Pond Turtle	assist in their recovery in order to contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of land and water in the Bay-Delta.
Swainson's Hawk	assist in the recovery of this State-listed threatened species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
Clapper Rail	assist in the recovery of this State- and federally listed endangered species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
California Black Rail	assist in the recovery of this State- listed threatened species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
Greater Sandhill Crane	assist in the recovery of this State-listed threatened species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
Western Yellow-Billed Cuckoo	assist in the recovery of this State-listed endangered species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

Species Type	Implementation Objectives
Bank Swallow	assist in the recovery of this State-listed threatened species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
Suisun Song Sparrow	assist in the recovery of this species of special concern in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
Salt Marsh Harvest Mouse	assist in the recovery of this State- and federally listed endangered species in order to contribute to overall species diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
Riparian Brush Rabbit	assist in the recovery of this State-listed endangered species in the Bay-Delta in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.
Shorebird and Wading Bird Guild	maintain healthy populations in order contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of land and water in the Bay-Delta.
Waterfowl	maintain healthy populations at levels that can support both consumptive and nonconsumptive uses, and contribute to the overall health and beneficial uses of the Bay-Delta.
Upland Game	maintain healthy populations at levels that can support both consumptive and nonconsumptive uses.
Neotropical Migratory Bird Guild	maintain healthy populations in order to contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of land and water in the Bay-Delta.
Lange's Metalmark, Delta Green Ground Beetle, and Valley Elderberry Longhorn Beetle	assist in maintaining populations of the Lange's metalmark, a federally listed endangered species, by increasing its abundance, and assist in the recovery of the delta green ground beetle and Valley elderberry longhorn beetle, both federally listed endangered species, by increasing their populations and abundance in order to contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of land water in the Bay-Delta.

TABLE 9. BASIS FOR SELECTION OF SPECIES AND SPECIES GROUP ECOSYSTEM ELEMENTS

Species and Species Groups	Basis for Selection as an Ecosystem Element
Delta Smelt	The delta smelt is a native estuarine resident fish that has been listed as threatened under the California and federal Endangered Species Acts.
Longfin Smelt	The longfin smelt is a native estuarine resident species and is designated as a species of special concern by DFG and a species of concern by USFWS.
Splittail	The splittail is a native resident fish that is proposed for listing under the federal Endangered Species Act and a candidate for listing under the California Endangered Species Act. The splittail also supports a small winter sport fishery in the lower Sacramento River.
White Sturgeon	The white sturgeon is an important native anadromous sport fish with high recreational and ecological value.
Green Sturgeon	The green sturgeon is designated as a species of special concern by DFG and a species of concern by USFWS.
Sacramento Fall-run Chinook Salmon	The chinook salmon is an important native anadromous sport and commercial fish with important ecological value. The fall-run race is the largest population of chinook salmon on the Sacramento River.
Sacramento Late-fall-run Chinook Salmon	The chinook salmon is an important native anadromous sport and commercial fish with important ecological value. The late-fall-run race on the Sacramento River is designated as a species of special concern by DFG and a species of concern by USFWS.
Sacramento Winter-run Chinook Salmon	The chinook salmon is an important native anadromous sport and commercial fish with important ecological value. The winter-run race is listed as endangered under the California and federal Endangered Species Acts.
Sacramento Spring-run Chinook Salmon	The chinook salmon is an important native anadromous sport and commercial fish with important ecological value. The spring-run race on the Sacramento River is designated as a closely monitored species by DFG and a species of concern by USFWS.
San Joaquin Fall-run Chinook Salmon	The chinook salmon is an important native anadromous sport and commercial fish with important ecological value. The fall-run race on the San Joaquin River is designated as a species of special concern by DFG and a species of concern by USFWS.
Steelhead Trout	The steelhead is an important native anadromous sport fish of high recreational and ecological value that is proposed for listing under the federal Endangered Species Act.

Species and Species Groups	Basis for Selection as an Ecosystem Element
Striped Bass	The striped bass is an important non-native anadromous sport fish with high recreational value. It also plays an important role as a top predator in the aquatic system.
American Shad	The American shad is an important non-native anadromous sport fish with high recreational value.
Resident Fishes	Resident fish species of the Delta include native and non-native species and are important ecologically and as indicators of ecosystem health. Some native species are important elements of the foodweb; others are important predators. Native resident fish have been in decline as a percentage of total fish species abundance in tributaries of the Bay-Delta/Central Valley watershed. Some non-native species are considered beneficial as prey species for other fish or as sport fish. Other species are considered undesirable because they compete with or are predators on native fish. Wakasagi is a close relative to delta smelt and could threaten the delta smelt population by interbreeding or by competing for habitat.
Marine Fishes	Marine fishes include many species that are abundant and important ecologically in the Bay and coastal waters. Two ecologically significant species are the Pacific herring and northern anchovy, whose young are critical in the foodweb of important anadromous fishes, including salmon and striped bass. The Pacific herring and northern anchovy are also important foodweb species for wildlife that forage for fish in the Bay-Delta (e.g., cormorants and terns).
Special-status Plant Species	Special-status plant species include plants associated with a wide variety of habitats including perennial grasslands (fragrant fritillary, recurved larkspur), tidal brackish and freshwater marsh complexes (Mason's lilaeopsis, Suisun Marsh aster, bristly sedge, mad-dog skullcap, Suisun thistle, soft bird'- beak, rose-mallow, Delta tule pea and Delta mudwort), aquatic habitat associated with shorelines of rivers and the Delta (eel-grass pondweed), vernal pools (Colusa grass, Boggs Lake hedge-hyssop, Contra Costs goldfields, alkali milk-vetch, dwarf downingia, Crampton's tuctoria, and heartscale), and inland dunes (Antioch Dunes evening primrose, Contra Costa wallflower). Protection, enhancing, or restoring these special-status plant species will necessarily rely on protecting, enhancing, and restoring the appropriate type of habitat.
Plant Community Groups	Plant community groups include aquatic habitat plant communities (pondweeds with floating and submerged leaves), tidal brackish and freshwater marsh plant communities (pickleweed series, saltgrass series, bulrush series, cattail series, and common reed series), seasonal wetland plant communities (northern claypan vernal pool communities, northern hardpan vernal pool communities, inland dune plant communities (Antioch Dunes plant community), and tidal riparian habitat plant communities (black willow series, narrowleaf willow series, white alder series, buttonbush series, Mexican elderberry series, and valley oak series).

Species and Species Groups	Basis for Selection as an Ecosystem Element
Western Spadefoot and California Tiger Salamander	The western spadefoot and California tiger salamander are amphibians designated as species of special concern.
California Red-legged Frog	The California red-legged frog is listed as a threatened species under the federal ESA.
Giant Garter Snake	The giant garter snake is listed as threatened under the California and federal ESAs.
Western Pond Turtle	The western pond turtle is designated as a species of special concern and a species of concern by DFG and USFWS, respectively.
Swainson's Hawk	The Swainson's hawk is listed as threatened under the California ESA.
California Clapper Rail	The California clapper rail is listed as endangered under the California and federal ESAs.
California Black Rail	The California black rail is listed as threatened under the California ESA.
Greater Sandhill Crane	The greater sandhill crane is listed as a threatened species under the California ESA.
Western Yellow-billed Cuckoo	The western yellow-billed cuckoo is listed as endangered under the California ESA.
Bank Swallow	The bank swallow is listed as threatened under the California ESA.
Suisun Song Sparrow	The Suisun song sparrow is a species of special concern.
Salt Marsh Harvest Mouse	The salt marsh harvest mouse is listed as endangered under the California and federal ESAs.
Riparian Brush Rabbit	The riparian brush rabbit is listed as endangered under the California ESA.
Shorebirds and Wading Birds	Many species of shorebirds and wading birds migrate through, winter, or breed in the Bay-Delta. These species are significant components of the ecosystem, are of high interest to recreational bird watchers, and contribute to California's economy through sales of equipment and other bird-watching-related expenditures.
Waterfowl	Many species of waterfowl migrate through, winter, or breed in the Bay-Delta. Waterfowl are significant components of the ecosystem, are of high interest to recreational hunters and bird watchers, and contribute to California's economy through the sale of hunting and related equipment.

Species and Species Groups	Basis for Selection as an Ecosystem Element
Upland Game	Upland game species are of high interest to recreational hunters in the Bay-Delta and contribute to California's economy through the sale of hunting-related equipment and expenditures.
Neotropical Migratory Birds	Many species of neotropical migratory birds migrate through or breed in the Bay-Delta. These species are significant components of the ecosystem, are of high interest to recreational bird watchers, and contribute to California's economy through sales of equipment and other bird-watching-related expenditures.
Lange's Metalmark	The Lange's metalmark is listed as endangered under the federal ESA.
Delta Green Ground Beetle	The delta green ground beetle is listed as endangered under the federal ESA.
Valley Elderberry Longhorn Beetle	The valley elderberry longhorn beetle listed as threatened under the federal ESA.

TABLE 10. ECOLOGICAL ZONES IN WHICH PROGRAMMATIC ACTIONS ARE PROPOSED THAT WILL ASSIST IN THE RECOVERY OF SPECIES AND SPECIES GROUPS

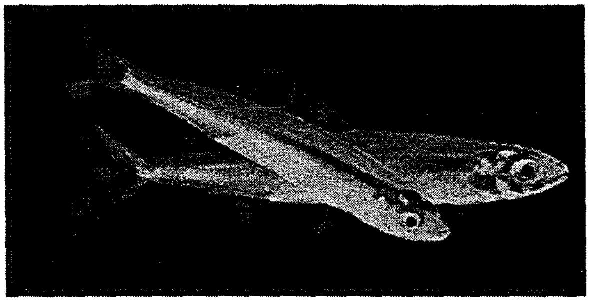
[Note: Refer to Volume II: Ecological Zone Visions for information regarding specific targets and actions.]

Species and Species Group Visions	Ecological Zone[1]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Delta Smelt	●	●												
Longfin Smelt	●	●												
Splittail	●	●	●					●	●		●	●		
White and Green Sturgeon	●	●	●					●						
Chinook Salmon	●	●	●	●	●		●	●	●	●	●	●	●	
Steelhead Trout	●	●	●	●	●		●	●	●	●	●	●	●	
Striped Bass	●	●	●					●	●					
American Shad	●	●	●					●	●			●		
Resident Fish Species	●	●								●	●			●
Bay-Delta Foodweb Organisms	●	●												
Marine/Estuarine Fishes and Large Invertebrates		●												
Special-status Plant Species														
Plant Community Groups														
Western Spadefoot and California Tiger Salamander	●													
California Red-Legged Frog	●													

Species and Species Group Visions	Ecological Zone[1]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Giant Garter Snake and Western Pond Turtle	●	●				●	●		●		●	●	●	
Swainson's Hawk	●	●							●		●	●	●	
California Clapper Rail		●												
California Black Rail	●	●												
Greater Sandhill Crane	●													
Western Yellow-Billed Cuckoo	●		●									●	●	
Bank Swallow				●										
Suisun Song Sparrow		●												
Salt Marsh Harvest Mouse		●												
Riparian Brush Rabbit	●												●	
Shorebird and Wading Bird Guild	●	●											●	
Waterfowl	●	●				●	●	●	●		●	●	●	●
Upland Game	●													
Neotropical Migratory Bird Guild	●											●	●	●

Species and Species Group Visions	Ecological Zone[1]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Lange's Metalmark, Delta Green Ground Beetle, and Valley Elderberry Longhorn Beetle	•	•												

[1] 1 = Sacramento-San Joaquin Delta
2 = Suisun Marsh/North San Francisco Bay
3 = Sacramento River
4 = North Sacramento Valley
5 = Cottonwood Creek
6 = Colusa Basin
7 = Butte Basin
8 = Feather River/Sutter Basin
9 = American River Basin
10 = Yolo Basin
11 = Eastside Delta Tributaries
12 = San Joaquin River
13 = East San Joaquin Basin
14 = West San Joaquin Basin



INTRODUCTION

The delta smelt is a native estuarine resident fish. Delta smelt are found mainly in the waters of the Sacramento-San Joaquin Delta and in Suisun and San Pablo Bays. They are found only in the Sacramento-San Joaquin Estuary. Delta smelt are most abundant in Montezuma Slough, Suisun Bay, and the western Delta, but beginning in December and continuing through perhaps June 30, migrate upstream and are more abundant in the Delta. They have been found as for upstream as the mouth of the American River on the Sacramento River as Mossdale on the San Joaquin River. Human-caused adverse habitat modifications reduced delta smelt populations resulting in its listing as threatened under State and federal Endangered Species Acts

Major factors that limit this species' contribution to the health of the Delta are adverse effects of low Delta outflow, poor foodweb productivity, reduced low-salinity habitat, losses to water diversions, poor spawning habitat, and potentially higher concentrations of toxins.

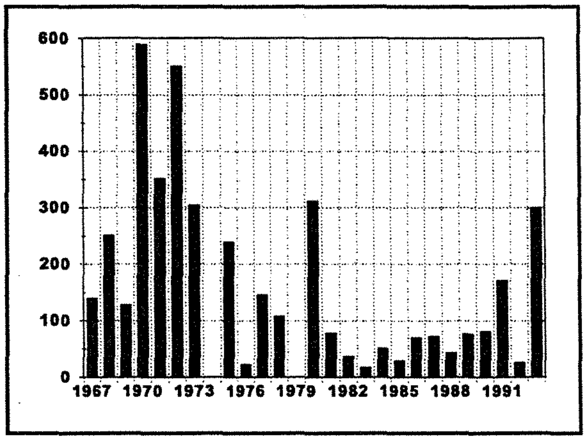
RESOURCE DESCRIPTION

Delta smelt are native to the Sacramento-San Joaquin Delta estuary and represent an important component of the historic native fish fauna and Bay-Delta foodweb (i.e., as a prey species for species such as chinook salmon). Delta smelt's 1-year life span and relatively low reproductive rate make its population abundance sensitive to short-term habitat changes. As a consequence, the population abundance of delta smelt is characterized by sharp declines followed by dramatic recovery. Low abundance through the drought years (1987-1992) indicated need for actions to restore the delta smelt population. Delta smelt are considered environmentally sensitive because the have a one year life cycle, unusually low fecundity, a limited diet, and reside primarily within the interface between salt and freshwater.

During the late winter to early summer, delta smelt migrate to freshwater to spawn. Females only produce between 1,000 and 2,600 eggs which sink to the bottom and attach to the substrate. Spawning habitat includes shallow freshwater sloughs and edge waters with firm substrate, submerged vegetation, and woody debris. Rearing habitat includes shallow freshwater and low salinity (less than 6-8 ppt salinity) habitats that provides a protective, food-rich environment. Such habitats include shallow bays, tidal sloughs, shoals, shorelines, and marsh channels.

Land reclamations in the Bay-Delta have diminished the quality and quantity of shallow-water, marsh-slough habitat. Remaining shallow-water, low-salinity habitat is further reduced in dry-water years because of extensive water diversions from the Delta.

Population abundance during 1993 and 1995 (relative to abundance during the 1987-1992 drought) suggests that recovery potential may be high. Sharp population decline during drought conditions (as in 1994), however, illustrates the potential threat of poor conditions to the species' survival under existing habitat and stressor



Abundance Data for Delta Smelt from DFG September and October Fall Mid Water Trawl Survey (USFWS 1996)

conditions. A preliminary low abundance index in 1996, a wet year, is further cause for concern. The fall mid water trawl (FMWT) is best measure of delta smelt abundance (Sweetnam and Stevens 1993) as it measures the abundance of pre-spawning adults. September and October abundances of adults were chosen as they represent the months most continuously samples during the last 30 years. It includes cumulative data for 35 sampling stations.

Delta smelt tolerate a wide range of salinity but are most abundant in the Bay-Delta estuary, where salinity is around 2 parts per thousand (ppt). Spawning occurs in freshwater in the upstream areas of the Delta. Construction of levees in the 1800s created narrow channels and eliminated vast areas of marshes and interconnecting sloughs. Marshes and adjoining sloughs are very productive and support an abundance of zooplankton, on which delta smelt feed, and are important as spawning and rearing habitat for the species.

Reduced freshwater outflow during the late winter and spring of dry years allows saltwater to move farther upstream in the estuary than during wet years. This reduces the amount of low-salinity habitat for delta smelt. The increased upstream saltwater movement changes the location of habitat that meets the salinity needs of the delta smelt, similar to effects on other Delta fish species such as striped bass, longfin smelt, and Sacramento splittail. Habitat location is shifted upstream from the relatively shallow, productive bays, marshes, and sloughs of Suisun Bay and into the narrow, deeper, and less-productive channels of the Delta.

The upstream shift also increases exposure to Delta water diversions. Water is drawn from the Delta by hundreds of small agricultural diversions, Central Valley Project (CVP) and State Water Project (SWP) South Delta export pumps, and Pacific Gas & Electric (PG&E) power generation facilities. During most years, large numbers of delta smelt are lost to Delta diversions.

Food availability, toxic substances, competition and predation (particularly from non-native species), and loss of genetic integrity through hybridization with the introduced Japanese pond smelt (wagasaki) also are other factors believed to influence smelt abundance.

Overall, the threats to the population, in decreasing order of importance, are:

- reduction in outflow from the Estuary,
- entrainment to water diversions,
- extremely high outflow,
- changes in food organisms,
- toxic substances,
- disease, competition, and predation, and
- loss of genetic integrity by hybridization with introduced wagasaki.

VISION

The vision for delta smelt is to ensure the recovery of this State- and federally listed threatened species in order to contribute to the overall species richness and diversity of the Bay-Delta. Achieving this vision will reduce the conflict between protection for this species and other beneficial water uses in the Bay-Delta. Increases in the population and distribution of delta smelt can be realized through habitat restoration accompanied by reductions in stressors.

Delta smelt would benefit from the many expected improvements in ecosystem processes and habitats, and reductions in stressors. Improvements in streamflow (Delta inflow and outflow) would better attract adults to spawning habitat, ensure transport or movement of larvae and early juveniles to productive rearing habitat, and maintain productivity and suitability of spawning and rearing habitat (including production of food). Additional freshwater flow could be provided reservoir releases during spring to maintain salinity requirements of delta smelt in areas that are good nurseries of delta smelt, such as Suisun Bay and Marsh.

Delta smelt would benefit from spawning and rearing habitat restoration. Habitat restoration may be achieved by adding and modifying physical habitat and creating additional freshwater flow during critical periods. More habitat can be created by breaching levees to inundate lands once part of the Bay and Delta, setting levees back to increase shallow-water habitat along existing channels, protecting existing shallow-water habitat from erosion, and filling relatively deep water areas with sediments to create shallow-water habitat.

Reducing stressors is a major component of delta smelt restoration. Reducing delta smelt losses to diversions is of primary concern.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore delta smelt involve cooperation and support of other established programs that are protecting and improving conditions for delta smelt and other species in the Bay and Delta.

- The Recovery Plan for the Sacramento/San Joaquin Delta native fishes (U.S. Fish and Wildlife Service 1996) would be considered in developing actions.

- The Central Valley Project Improvement Act will implement actions that will benefit delta smelt, including changing the timing of diversions, restoring habitat, and dedicating flow during critical periods (U.S. Fish and Wildlife Service 1997).

- Federal ESA requirements (biological opinions and habitat conservation plans) will ensure maintenance of existing habitat conditions and implement recovery actions.

- The State Water Resources Control Board will implement the Water Quality Control Plan for the San Francisco/Sacramento-San Joaquin Delta estuary, which includes provisions to limit entrainment in diversions and protect habitat conditions for delta smelt, chinook salmon, striped bass, and other species.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Successful restoration of delta smelt will be closely tied with improving late winter and spring Delta outflow, increasing shallow water and wetland-slough habitat, improving the productivity of the aquatic foodweb, reducing the effects of Delta water diversions, and reducing the level of contaminants in Bay-Delta waters. Restoration actions are similar to those prescribed for other native resident and anadromous fish including longfin smelt and striped bass.

Maintenance of rearing habitat is extremely important for the recovery of delta smelt and other native Delta species. Successful restoration of delta smelt will also be closely tied with improving Delta outflow that maintains the X2 location in Suisun Bay for rearing delta smelt and prevents adverse influence of the CVP/SWP export facilities in the southern Delta.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for delta smelt is to ensure the recovery of this species, which is State- and federally listed as threatened, in order to contribute to overall species richness and diversity and reduce the conflict between the need for its protection and other beneficial uses of water in the Bay-Delta.

The targets for delta smelt include exceeding a fall midwater trawl catch index of 240 in dry water-year types and a wider distribution of delta smelt in the trawl survey.

The following actions would contribute to improving the delta smelt population:

- Improve Delta outflow during the late winter and spring to improve foodweb productivity and to disperse larvae and juveniles to downstream rearing habitat in Suisun Bay.
- Maintain Delta outflow once larvae and juveniles have reached downstream rearing habitat to keep them beyond the "zone of influence" of the CVP/SWP and agricultural diversions,
- Increase the residence time of X2 at key locations in Suisun Bay (e.g., Roe Island, Chipps Island, and Collinsville).
- Reduce adverse effects of CVP and SWP diversions during the period when larvae, juveniles, or adult life stages appear in the Delta.
- Adult delta smelt captured in late winter and early spring at the Delta fish facilities should be released upstream to complete their spawning migration. Adults captured at other times should be released downstream.
- Increase the amount of shallow-water habitat in areas critical to spawning and rearing.
- Construct and improve fish facilities for Delta diversions, including agricultural diversions and CVP and SWP diversions, and improve handling and salvage practices at diversions.
- Develop and implement a program to reduce the adverse effects of introduced aquatic species and the potential for future introductions.
- Implement restoration actions identified in the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes Recovery Plan.

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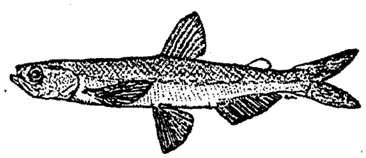


INTRODUCTION

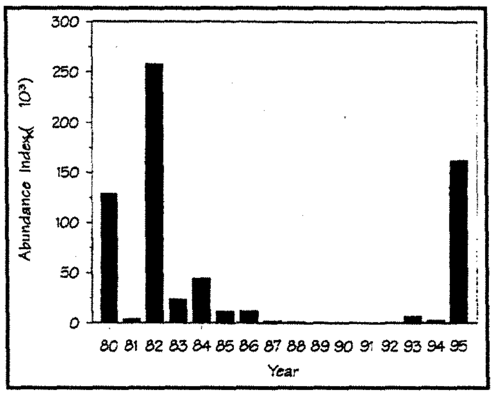
Longfin smelt are small native fish that live in the brackish waters of San Francisco Bay and the Delta. They are an important element of the Bay-Delta foodweb as prey for chinook salmon, striped bass, and other predatory fish species. Because their abundance dropped sharply during dry periods over the past several decades, they are designated by the California Department of Fish and Game (DFG) and U.S. Fish and Wildlife Service (USFWS) as a species of special concern. Longfin smelt abundance was especially low during the 1987-1992 drought and showed signs of recovery only in 1995.

Major factors that limit this species' contribution to the health of the Delta are related to the adverse effects of low Delta outflow and include associated poor foodweb productivity, greater effects of water diversions, poorer larval transport and habitat conditions, and potentially higher concentrations of toxins that may limit its survival and production during droughts.

RESOURCE DESCRIPTION

A population of longfin smelt lives within the brackish water and saltwater of northern San Francisco Bay and migrates upstream into the Delta to spawn. Longfin smelt are well-adapted to the Bay-Delta estuary and are also found in other west-coast estuaries from northern California to southern Alaska.

Adult longfin smelt migrate upstream each winter from the Bay to spawn in freshwater portions of the upper Bay and Delta. Spawning occurs in habitats with hard-bottom or plant substrates such as tidal wetlands and channels. Most spawning takes place from late December through April. High winter and early spring flows transport newly hatched larvae downstream into Suisun and San Pablo Bays, where the plankton food supply is characteristically abundant and necessary for high survival of longfin smelt larvae and juveniles.



Longfin Smelt Young Index in IEP Bay Study Trawl Survey

Longfin smelt abundance has been monitored by DFG in the Bay and Delta each fall since 1967. Population rates have fluctuated sharply, with greatest abundance in wetter years in wet-year sequences (1967, 1969, and 1971 from 1967- 1971; and 1980, 1982, and 1983 from 1980-1983). Abundance has been very poor in drought periods (1976-1977 and 1987-1992). Low abundance in 1993, the first wet year following the drought from 1987 to 1992, may reflect a greatly reduced spawning population resulting from drought conditions. Improved abundance in 1995 indicates that they may be recovering from the effects of the drought.

A similar pattern of population abundance is evident since 1980 in DFG's Bay trawling survey and the University of California, Davis' trawl survey in Suisun Marsh. Abundance was high from 1980 through 1984, but declined to very low levels through the 1987-1992 drought and has recovered only slightly since 1995.

The decline in the longfin smelt population has coincided with a number of changes in the estuary. Related stressors believed to contribute to this decline are listed below.

Low flows in late winter and spring into and through the Delta are believed to reduce survival of eggs and larval longfin smelt spawned in the Delta. Low Delta outflows may limit transport of larval and juvenile longfin smelt downstream into quality nursery grounds of Suisun and San Pablo Bays. Low flows are a consequence of climatic conditions (low rainfall and more precipitation as winter rains rather than snow) and upstream reservoir storage of winter and spring runoff in dry and normal years.

Reduced freshwater flows through the Delta and into Suisun Bay may limit production of foodweb organisms during the critical early life stages of longfin smelt.

Water diversion practices, especially in drier years, reduce larvae (about 5-15 millimeters long) and adult populations and lower reproduction rates. In drier years, the percentage of freshwater diverted is sharply higher than in wetter years.

Power plants at Pittsburg and Antioch with the largest diversions (up to 3,000 cubic feet per second) operate in the prime nursery area of the western Delta and Suisun Bay. The power plants operate longer in winter and spring of dry years (when less hydroelectric power is produced) to meet regional electricity demands.

Similarly, Delta agricultural diversions are generally confined to late spring through fall; however, spring diversions are generally greater in drier years, when irrigation needs are higher. Although larvae losses to south Delta Central Valley Project and State Water Project pumping plants are generally much lower than losses to more northern and western Delta diversions, they are higher in drier years when Delta outflow is insufficient to move larval longfin smelt out of the Delta into the Bay.

In dry years, many larval and juvenile longfin smelt rearing in the Delta are drawn south across the Delta toward the south Delta pumping plants by the net southward flow caused by water exports at the pumping plants. Many probably perish before reaching the pumps as a result of poor food supply, poor water quality (mainly high water temperature), and predation in the central and south Delta channels, and intake forebays and structures of the pumping plants. Of those reaching the pumping plants, some are recovered in fish salvage facilities and returned to the Bay, while others are lost in water exported.

The number of adults making the upstream spawning run has dropped to such low levels in recent years that they no longer spawn sufficient numbers of eggs to bring about quick recovery in wet years. This may explain why production in 1993 was lower than expected.

Contaminants in the Delta water may also reduce the survival of longfin smelt. The effect may be indirect through reduced planktonic food supply or direct from toxin-induced egg, larval, or juvenile stress or mortality.

Other more speculative causes of the decline and low abundance of longfin smelt include competition or predation. Recently established non-native fishes, such as gobies introduced from the ballast water of ships from Asia, compete with longfin smelt. Predation in dry years may also be a problem, although it is difficult to quantify the potential adverse effects. Management programs that should be evaluated for potential adverse influence on longfin smelt and other native fish populations include the juvenile striped bass stocking program and salmon hatchery release programs. The striped bass stocking program has released over 11 million juvenile striped bass from 1985 through 1990 into San Pablo and Suisun Bays and Central Valley salmon hatcheries have released millions of hatchery-reared salmon smolts into San Pablo Bay in spring each year. Changes in plankton abundance and community species composition of the Bay and Delta caused by the introductions of non-native species of zooplankton and Asian clams may also have contributed to the decline of longfin smelt by affecting their food supply.

Overall, the longfin smelt are affected by the following factors in approximate order of importance (U.S. Fish and Wildlife Service 1996);

- reductions in Delta outflows,
- entrainment losses at water diversions,
- climatic variations (droughts and extreme floods),
- toxic substances,
- predation, and
- adverse effects of introduced species.

VISION

The vision for longfin smelt is to improve the population of this species of special concern in the Bay-Delta estuary so that it resumes its historical levels of abundance and its role as an important prey species in the Bay-Delta aquatic foodweb.

Achieving consistently high production of longfin smelt in normal and wetter years, which historically produced more abundant juvenile populations (year classes), will be critical to the recovery of longfin smelt. Good wet-year production would be ensured by (1) not allowing production to fall too low in drier years such that numbers of adult spawners in subsequent wet years remains low, (2) maintaining and improving spawning and rearing habitat, and (3) minimizing stressors in wetter years.

Longfin smelt recovery efforts will also focus on enhancing freshwater outflow in dry and normal water year types during winter spawning and early rearing periods. Natural Delta outflows in dry and below- and above- normal water-year types have been reduced, particularly in late winter and spring, and such reductions coincide with the longfin smelt decline. The 1995 Water Quality Control Plan for the Delta provided interim provisions for increasing February-through-June Delta outflows. Additional improvements in late-winter and spring outflows would:

- improve transport of larvae and juveniles from Delta spawning areas to Bay rearing areas,
- limit the extent of total southerly flows toward the south Delta pumps where larvae and juveniles are subject to being exported,
- improve survival and production of longfin smelt by stimulating foodweb productivity, and
- dilute concentrations of contaminants that may be detrimental to longfin smelt or their food supply.

Although deterioration of habitat is not considered a major factor in the decline of longfin smelt, protecting, improving, and restoring shallow-water habitat in the Bay-Delta would help to increase survival and production of longfin smelt. Improved habitat would provide spawning and rearing habitat and increasing foodweb production. The increased spawning area and improved food supply may help to overcome other factors that have little potential for change (e.g., competition and predation from non-native species). Increases in tidal wetlands will provide tidal channels that are important spawning and rearing habitat. Improving and restoring shallow waters and riparian vegetation along levees and channel islands in the Delta will also provide additional important spawning habitat. Habitat improvements are expected to also increase the abundance of plankton, on which longfin smelt feed, and lead to improved survival of larvae and juveniles.

The Recovery Plan for Native Resident Fishes of the Sacramento-San Joaquin Bay-Delta Estuary (Recovery Plan) recommends restoring spawning and rearing habitat in shallow Delta islands (i.e., Prospect Island, Hastings Tract, Liberty Island, New Hope Tract, Brack Tract, and Terminous Tract) (U.S. Fish and Wildlife Service 1996). The Recovery Plan also recommends restoring tidal shallow-water habitat in Suisun Marsh by reclaiming leveed lands.

In addition to improving Delta outflow and habitats, reducing stressors will be important in restoring longfin smelt populations. Water diversions remove many longfin smelt and their food supply from the Bay and Delta, particularly during drier years. Losses to diversions should be reduced.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Restoring longfin smelt in the Central Valley is will involve cooperation with the following programs.

- Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (U.S. Fish and Wildlife Service 1995a): Its purpose under the federal Endangered Species Act is to provide a strategy for the conservation and restoration of Delta native fishes. Longfin smelt are identified in this plan as requiring prompt restoration actions. The basic objective of this plan is to establish self-sustaining populations of the species of concern, including longfin smelt, that will persist indefinitely. The vision for longfin smelt includes facilitating implementation of the Recovery Plan.

- The Central Valley Project Improvement Act (PL 102-575): It calls for the doubling of the anadromous fish populations (including striped bass, salmon, steelhead, sturgeon, and American shad) by 2002 (U.S. Fish and Wildlife Service 1995b). This program involves actions that may indirectly benefit longfin smelt.

- The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988: DFG is required under State legislation to restore numbers of anadromous fish in the Central Valley (California Department of Fish and Game 1993). Actions include restoring the food supply of anadromous fish; that food supply includes longfin smelt.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Successful restoration of longfin smelt will be closely tied with improving late winter and spring Delta outflow, increasing shallow water and wetland-slough habitat, reducing the effects of Bay-Delta water diversions, and reducing the level of contaminants in Bay-Delta waters. Restoration actions are similar to those prescribed for other native resident and anadromous fish including delta smelt and striped bass.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for longfin smelt is to ensure the recovery of this species of special concern in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of water in the Bay-Delta.
A target for longfin smelt is to increase their abundance as measured in the fall midwater trawl survey especially in dry year and in wet year following dry year or series of dry years. Another

target is to increase their distribution to a wider areas of the Bay-Delta as measured in the trawl survey.

The following actions would improve the longfin smelt population:

- Improve Delta outflow in late winter and spring to improve foodweb productivity and to dispense larvae and juvenile longfin smelt to downstream rearing habitat in Suisun and San Pablo Bays.
- Increase the amount of shallow water spawning habitat in the Delta and rearing habitat in Suisun and San Pablo Bays.
- Relocate or add diversion options for the south Delta pumping plants to (1) alleviate net southerly flows in the Delta in drier years, (2) improve transport of young longfin smelt to the Bay and away from the south Delta pumping plants and Delta agriculture diversions, and (3) increase the foodweb productivity.
- Evaluate and implement options to reduce PG&E power plant diversions from February through July in drier years. Options include limiting power operations during critical periods; improving screening facilities to reduce entrainment of larval and early juvenile longfin smelt, life stages that are presently most vulnerable to the intakes; or retrofitting plants with alternative cooling technologies (e.g., cooling towers).
- Evaluate the need to alter the timing and location for stocking striped bass and hatchery-reared chinook salmon in spring and early summer to avoid important longfin smelt juvenile rearing areas in Suisun and San Pablo Bays.
- Develop and implement a program to reduce the introduction of non-native species to the estuary from released ballast water would help minimize increases in predation and competition.
- Develop and implement a program to reduce contaminant inputs to the Bay-Delta would indirectly improve production of longfin smelt.

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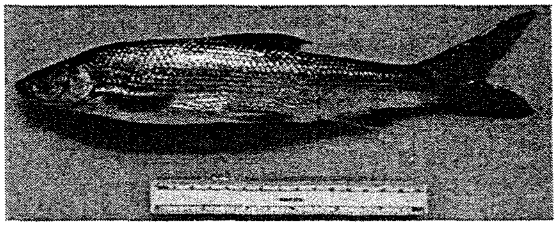
U.S. Fish and Wildlife Service. 1996. Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes. U.S. Fish and Wildlife Service, Portland, OR.



INTRODUCTION

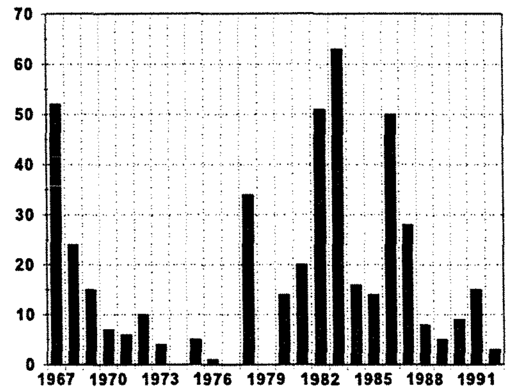
The splittail is a native resident fish of the lower reaches of the Sacramento and San Joaquin Rivers. It is proposed for listing under the federal Endangered Species Act and a candidate for listing under the California Endangered Species Act. The splittail also supports a small winter sport fishery in the lower Sacramento River.

Major factors that limit its contribution to the health of the Bay-Delta include loss of floodplain spawning and rearing habitat, low streamflows that limit floodplain inundation and transport young to downstream nursery areas, and losses to water diversions.

RESOURCE DESCRIPTION

Splittail are endemic to the Sacramento-San Joaquin Delta estuary and to the lower reaches of the Sacramento and San Joaquin Rivers. Splittail represent an important component of the historical native fish fauna. Splittail tolerate a wide range of salinity, but are most abundant in shallow areas where salinity is less than 10 parts per thousand (ppt). Spawning occurs in fresh water, primarily in floodplain areas upstream of the Delta. Spawning habitat includes shallow edgewaters and seasonally flooded riparian zones and flood bypass areas that provide spawning substrate (e.g., submerged vegetation). Rearing habitat includes shallow- fresh- and brackish water (less than 10 ppt salinity) habitat that provide a protective, food-rich environment.

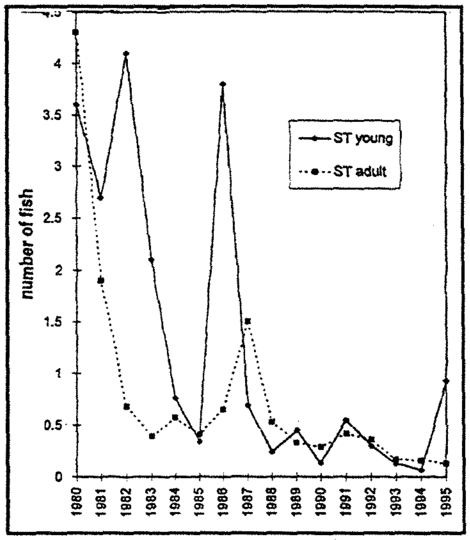
The population abundance of splittail is highly variable. Year-class abundance varies greatly. Low year-class success occurred throughout the 1987-1992 drought years.



Abundance Data for Splittail from DFG Fall Mid Water Trawl Survey (USFWS 1996)

Access to habitat throughout the geographic range of splittail has been greatly diminished by human-caused actions. Restrictions to the floodplain, loss of marshes, and reduced winter-spring river flows from flood control and water supply development have reduced the species' range and abundance. In addition, water quality (e.g., high temperature and dissolved solids) reduce the use of the lower San Joaquin River by splittail.

Splittail have limited productivity particularly in periods of drought, primarily from low freshwater inflow to the Bay-Delta and modification of habitat by past and ongoing human actions. Dams and levees restrict access to historical, seasonally flooded spawning and rearing habitat. Abundant year classes are generally associated with winter



Index of Adult and Juvenile Splittail
in Suisun Marsh Trawl Survey

and spring flows sufficient to flood peripheral areas of the Delta and lower river reaches, including the flood bypass system of the Sacramento River and the floodplain of the San Joaquin River. Flood control reservoirs reduce flooding in the Sacramento, San Joaquin, American, Feather, Mokelumne, Stanislaus, Tuolumne, Merced, and Calaveras Rivers.

Levee construction in the 1800s created narrow channels and eliminated vast areas of fluvial marsh and seasonal wetlands that are important as spawning and rearing habitat for splittail.

Losses to Delta diversions (e.g., hundreds of small agricultural diversions, Central Valley Project [CVP] and State Water Project [SWP] export pumps, and Pacific Gas & Electric Company [PG&E] power generation facilities) reduce splittail abundance. Large numbers of young splittail are entrained in Delta diversions, especially during years coinciding with high reproductive success.

Food availability, toxic substances, and competition and predation (particularly from striped bass and other introduced species) are among the factors limiting splittail abundance. In addition, harvest for food and bait by sport anglers may inhibit recovery of the splittail population.

VISION

The vision for splittail is to assist in the recovery of the species in order to contribute to the overall species richness and diversity, and to reduce the conflict between protection for this species and other beneficial uses of water in the Bay-Delta.

Splittail would benefit from improvements in spawning and rearing habitat, late winter and spring river flows, and reduced losses to water diversions. Increases in the frequency of floodplain inundation, and increased freshwater flows would contribute most to their recovery. Additional freshwater flow could be provided during late winter and spring to attract adults to upstream spawning areas, transport young to downstream nursery areas in the Bay-Delta, and maintain low salinity habitat in the western Delta and Suisun Bay.

Restoring splittail will require restoring seasonally flooded spawning and rearing habitat. Habitat restoration may be achieved by adding and modifying physical habitat and additional freshwater flow during critical periods. Actions include breaching levees to inundate existing islands, setting levees back to increase shallow-water habitat along existing channels, protecting existing shallow-water habitat from erosion, and filling deep water areas with sediments to create shallow-water habitat.

Splittail would benefit from reduced-widow losses to diversions in the Sacramento and San Joaquin Rivers and the Sacramento-San Joaquin Delta estuary.

Integration with Other Restoration Programs

Efforts to restore splittail would involve cooperation and support from other established programs that are protecting and improving conditions for delta smelt, striped bass, and other species.

- Recovery Plan for the Sacramento/San Joaquin Delta native fishes (U.S. Fish and Wildlife Service 1995) will be considered in developing program actions.
- Central Valley Project Improvement Act (CVPIA) will implement actions that will benefit splittail, including changing timing of diversion, restoring habitat, and dedicating flow during critical periods for co-occurring species.
- State Water Resources Control Board (SWRCB) will implement the Water Quality Control Plan for the San Francisco/Sacramento-San Joaquin Delta estuary, which includes provisions to limit entrainment in diversions and protect habitat conditions for splittail, chinook salmon, striped bass, and other species.

Linkage with Other Ecosystem Elements

Successful restoration of splittail will be closely tied with improving freshwater inflow, floodplain inundation, wetland restoration, and reducing effects of water diversions. Restoration actions are similar to those prescribed for other native resident fishes including delta smelt.

Implementation Objectives, Targets, and Programmatic Actions

The implementation objective for splittail is to ensure the recovery of this species of special concern, which is proposed for listing under the federal Endangered Species Act (ESA), in order to contribute to overall species richness and diversity and reduce the conflict between the need for its protection and other beneficial uses of water in the Bay-Delta.

The targets for splittail include achieving a fall mid-water trawl index consistently of 20 units or higher, and a Suisun Marsh trawl index consistently of 4 units or higher.

The following actions would improve the splittail population:

- improve late winter and spring freshwater flows,
- increase flooded and shallow water spawning habitat in rivers and Bay-Delta,
- upgrade existing fish protection facilities at south Delta pumping plants,
- install fish screens on currently unscreened facilities in the Delta and Sacramento and San Joaquin Rivers,
- remove predators associated with diversions and fish protection facilities,
- relocate and consolidate existing diversions,
- change seasonal timing of diversions,
- reduce or eliminate diversions,
- reduce pollutant input to streams and rivers in the Sacramento-San Joaquin River basin,

- prevent introduction of non-native species. High water temperatures and dissolved solids also reduce splittail use of the lower San Joaquin River.

REFERENCES

U.S. Fish and Wildlife Service. 1996. Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes. U.S. Fish and Wildlife Service, Portland, Oregon.

INTRODUCTION

White and green sturgeon rear in the Sacramento-San Joaquin estuary and spawn in the Sacramento and San Joaquin Rivers and their major tributaries. Sturgeon may leave the Bay-Delta and move along the coast to as far as Alaska. Populations of white and green sturgeon are found in many of the larger rivers from California north to British Columbia.

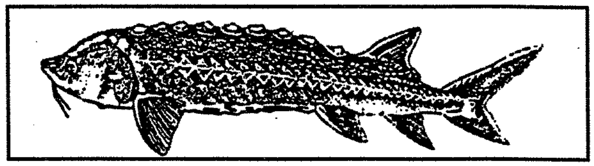
The white sturgeon is an important native anadromous sport fish with high recreational and ecological value. The green sturgeon is designated as a species of special concern by the California Department of Fish and Game (DFG) and U. S. Fish and Wildlife Service (USFWS).

Major factors that limit sturgeon populations in the Bay-Delta are adequate streamflows for attracting adults to spawning areas in rivers and transporting young to nursery areas, illegal and legal harvest, and entrainment into water diversions.

RESOURCE DESCRIPTION

White and green sturgeon are native to Central Valley rivers and the Bay-Delta and represent an important component of the historic native fish fauna. Throughout recorded history, white sturgeon have been the dominant sturgeon populations in the Bay-Delta system, whereas in smaller systems such as the Eel River, green sturgeon dominate. White sturgeon support a valuable sport fishery in the Bay and Delta.

Sturgeon are long-lived species. Change in abundance of older fish may reflect the harvest of



adults and habitat conditions that occurred decades ago during the larval and early juvenile life stages.

White and green sturgeon inhabit both saltwater and fresh water and tolerate a wide range of salinity concentrations. Spawning occurs in larger rivers upstream of the Delta. Low river flow during late winter and spring may reduce attraction of sturgeon to specific rivers and reduce spawning success. Stream channelization and flood control measures on large rivers (e.g. levee construction) may affect sturgeon use and spawning success.

Losses of sturgeon young into water diversions reduces sturgeon productivity. However, relative to other species, the percentage of the sturgeon population caught in diversions is low.

Food availability, toxic substances, and competition and predation are among the factors influencing the abundance of sturgeon. Sturgeon are long lived (e.g., some live over 50 years) and may concentrate pollutants in body tissue from eating contaminated prey over long periods. Harvesting by sport fishers also affects abundance of the adult populations. Illegal harvest (poaching) also reduces the adult population.

Recently, white sturgeon have been feeding on Asian clams in Suisun Bay, which may indicate a very important ecological role that could feed back through foodweb productivity of the Bay-Delta. Sturgeon predation may limit clam abundance and therefore potentially decrease the loss of plankton to clam feeding. The clams also accumulate contaminants, which may pose a long-term problem for sturgeon feeding heavily on clams.

VISION

The vision for white and green sturgeon is to restore population distribution and abundance to historical levels. Restoration of these species would support a sport fishery for white sturgeon, ensure recovery of the green sturgeon population, and contribute to overall species richness and diversity and reduce conflict between the need for protection for these species and other beneficial uses of water in the Bay-Delta.

White and green sturgeon would benefit from improved ecosystem processes, including adequate streamflow to attract adults to spawning habitat, transport larvae and early juveniles to productive rearing habitat, and maintain productivity and suitability of spawning and rearing habitat (including production of food). Ecosystem processes that need improvement include streamflows, stream and channel configurations, and migration barriers (e.g. dams). Additional streamflow during late winter and spring would attract sturgeon to rivers and maintain spawning flow requirements.

White and green sturgeon would benefit from restoring spawning and rearing habitat. Habitat restoration may be achieved by adding and modifying physical habitat and increasing freshwater flow during critical periods. Juvenile sturgeon frequent Delta sloughs and may benefit from increases in slough habitat. Spawning habitat includes upstream river reaches that contain appropriate substrate (e.g., gravel, rock). Rearing habitat includes areas in the Sacramento and San Joaquin Rivers and the Delta that provide protective, food-rich habitats such as the shallow shoals and bays of the Bay-Delta.

Reducing stressors is a component of restoring white and green sturgeon populations. Reducing losses to diversions from the Sacramento-San Joaquin Delta estuary would increase survival of young sturgeon. White and green sturgeon would also benefit from actions to reduce pollutant input to streams and rivers in the Sacramento-San Joaquin River basin.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore white and green sturgeon in the Central Valley would involve cooperation and support from other programs underway to restore sturgeon and other important fish.

- The Central Valley Project Improvement Act (CVPIA) (PL 102-575) calls for implementing changes in flows and project facilities and operations by 2002 that lead to doubling of the sturgeon populations.
- The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 requires DFG to restore historical numbers of sturgeon in the Central Valley.
- The Four Pumps (SWP) and Tracy (CVP) Fish Agreements provide funds and actions to DFG for sturgeon restoration.
- The Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes (USFWS) identifies recovery actions for white and green sturgeon.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration of white and green sturgeon populations are integrally linked with restoration of river floodplain and stream meander habitat, improvements in Central Valley streamflows, improvements in habitat, and reductions in losses to water diversions and illegal harvest.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for white sturgeon and green sturgeon is to restore the distribution and abundance of the white sturgeon to historical levels in order to support a sport fishery, and ensure the recovery of the green sturgeon, a DFG species of special concern. Meeting this objective would contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of water in the Bay-Delta.

General targets for sturgeon populations are:

- Restore population to levels of the 1960s,
- Improve flow in Sacramento River in spring,
- Reduce the rate of illegal harvest,
- Reduce the percentage lost of sturgeon to water diversions to that of the 1960s,

The general approach for programmatic actions are:

- Improve the aquatic foodweb,
- Improve spring flows in Sacramento River and major tributaries,
- Restore natural meander belts and add gravel substrates in upstream spawning areas,
- Increase Delta outflow in spring of dry and normal years,
- Improve water quality of Bay-Delta,
- Provide greater enforcement to reduce poaching,
- Reduce losses of eggs, larvae, and juvenile sturgeon at water diversions,
- Upgrade fish protection facilities at diversion facilities in the Delta,
- Restore tidally influenced Delta and estuarine habitat such as tidal perennial aquatic habitat and sloughs.

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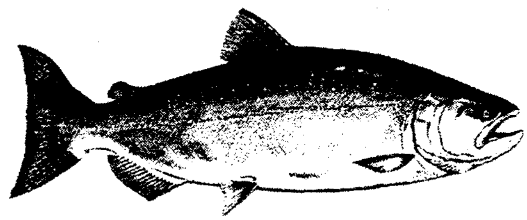


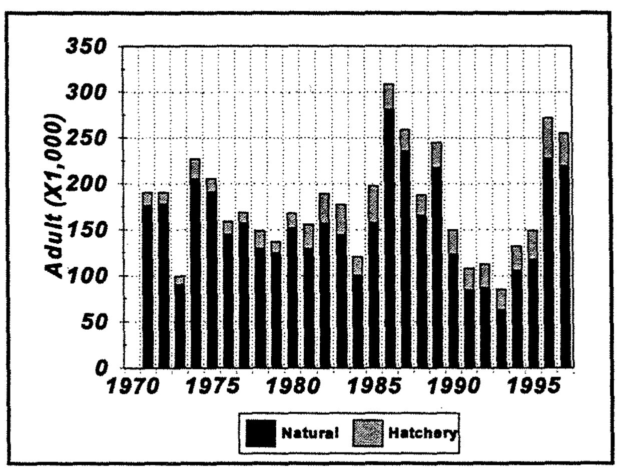
INTRODUCTION

Chinook salmon are medium- to large-bodied fish that spawn in freshwater, migrate to the ocean as juveniles, achieve significant growth, and return to freshwater at varying degrees of sexual maturity. Four runs of chinook salmon are present in the Central Valley, distinguished by their timing of reentry to fresh water: fall, late-fall, winter, and spring (Boydstun et al. 1992). Winter-run chinook salmon were formally listed as an endangered species under the California Endangered Species Act in 1989, and as endangered under the federal Endangered Species Act in 1994 (National Marine Fisheries Service [NMFS] 1996). The NMFS is reviewing the status of the other Central Valley chinook salmon runs and considering the potential needs for additional listings under the ESA. Listing of the winter-run chinook population reflected poor ecological health of the Bay-Delta system and placed additional regulatory controls on water management operations in the Central Valley. Water management regulations constrain the water diversion from the Sacramento River, the water export in the Delta, and restrict ocean harvest.

The key to improving chinook salmon populations will be maintaining populations through periods of drought by improving streamflow magnitude, timing, and duration; reducing the effects of the CVP/SWP export pumps in the southern Delta which alter Delta hydrodynamics, juvenile rearing and migration patterns, and cause entrainment at the facilities, and reducing stressors such as unscreened water diversions, high water temperatures, and harvest of naturally spawned salmon. The overall nature of habitats, flows, and stressors varies greatly throughout the range of chinook salmon in the Central Valley and is influenced by which specific run of salmon is present, its life stage (egg, fry, juvenile, adult), and the season.

RESOURCE DESCRIPTION

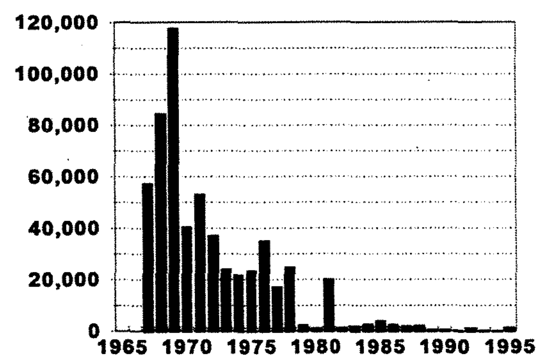
Chinook salmon represent a highly valued biological resource and a significant biological legacy in the Central Valley of California. Central Valley chinook salmon comprise numerous individual stocks, including the Sacramento fall-run, late-fall-run, spring-run, winter-run, and San Joaquin fall-run. The continued existence of Central Valley chinook salmon is closely linked to overall ecosystem integrity and health.



Central Valley Adult Fall-run Chinook Salmon Escapement Estimates for Natural and Hatchery Spawners (PFMC 1997)

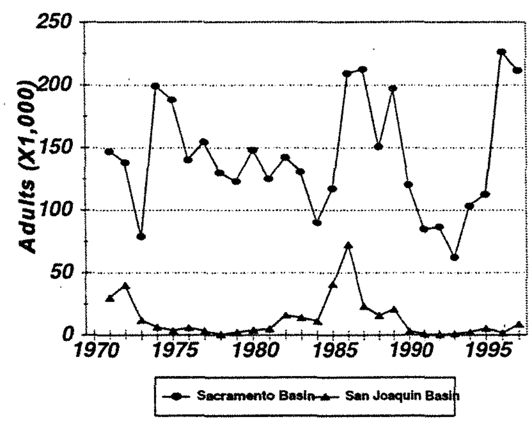
Because of their life cycle, typical of all Pacific salmon, Central Valley chinook salmon require high-quality habitats for migration, holding, spawning, egg incubation, emergence, rearing, and emigration to the ocean. These diverse habitats are still present throughout the Central Valley and are successfully maintained to varying degrees by existing ecological processes. Human-caused actions (stressors) have diminished the quality and accessibility of habitats used by chinook salmon. These habitats can be restored through a comprehensive program that strives to restore or reactivate ecological processes, functions, and habitat elements on a systematic basis, while reducing or eliminating known sources of mortality and other stressors that impair the survival of chinook salmon. However, the restoration approach must fully consider the problems and opportunities within each individual watershed and must be fine tuned to meet the requirements of locally adapted stocks.

Chinook salmon populations in the Central Valley are at varying degrees of health. Some populations, such as the winter-run and spring-run, have declined sharply over the past one to two decades. Winter-run has been designated as an endangered species and the spring-run and San Joaquin fall-run are being considered for listing as threatened. Some populations remain healthy, especially those supplemented with hatchery production.



Annual escapement estimates for winter-run chinook salmon.

Overall, the abundances of stocks have varied annually since 1970 and exhibited depressions in run size (escapement) during and following the 1976-1977 and 1987-1992 droughts (Mills and Fisher 1994). Low flows and reservoir storage levels during droughts caused high water temperatures, poor spawning and rearing habitat conditions, high predation rates, high diversion losses, and increased harvest, which in turn reduce salmon survival.



Comparison of the escapement trends of adult fall-run chinook salmon in the Sacramento Basin and the San Joaquin Basin (PFMC 1997).

Chinook salmon are found in virtually all 14 ecological zones that comprise the ERPP Study Area and many of their respective ecological units. Overall, the decline of the chinook salmon population resulted from the cumulative effects of degrading spawning, rearing, and migration habitats in the Sacramento and San Joaquin basins and the Sacramento-San Joaquin Delta. Specifically, the decline was most likely caused by a combination of factors that reduced or eliminated important ecological processes and functions, such as:

- excessively warm water temperatures during the prespawning, incubation, and early rearing periods of juvenile chinook;
- interrupting or blocking the free passage of juveniles and adults at diversion and water storage dams;

- loss of natural emigration cues when flow regimes are altered as a result of the export of water from large diversions in the south Delta;

- heavy metal contamination from sources such as Iron Mountain Mine;

- entrainment in a large number of unscreened and poorly screened diversions; and

- degradation and loss of woody debris, shaded riverine aquatic (SRA) habitat, riparian corridors and forests, and floodplain functions and habitats from such factors such as channelization, levee construction, and land use.

Climatic events and human activity have exacerbated these habitat problems. Lengthy droughts have led to low flows and higher temperatures. Periodic El Niño conditions in the Pacific Ocean have reduced salmon survival by altering ocean current patterns.

Human activities have also contributed to the decline of the chinook, although perhaps to a lesser degree. These activities include the construction and operation of various smaller water manipulation facilities and dams; levee construction and marshland reclamation causing extensive loss of rearing habitats in the lower Sacramento River, San Joaquin River, and Sacramento-San Joaquin Delta; and introduction of predatory species. Ocean and inland recreational and commercial salmon fisheries have probably impaired efforts to rebuild salmon stocks.

Existing regulatory efforts have not adequately maintained some chinook stocks as healthy populations. As a result, the winter-run population was protected under the State and federal ESAs to save it from extinction. Since its listing, some significant habitat improvements have been made to help preserve this and other chinook populations. These include improved water temperatures and flow management for spawning, incubation, and rearing; improved passage of juveniles and adults at diversions and dams on the upper Sacramento River; reduced diversions during periods when juveniles are most susceptible to entrainment; and the positive-barrier fish screens installed on the larger water diversions along the Sacramento River. However, additional measures that focus on reactivating or improving ecological processes and functions that create and maintain habitats will be necessary for recovery of the various chinook salmon stocks in the Central Valley.

Rebuilding chinook populations to a healthy state will require a coordinated approach to restoring ecosystem processes and functions, restoring habitat, reducing or eliminating stressors on a site-specific basis, and improving management and operation of the five salmon hatcheries in the Central Valley.

VISION

The vision for Central Valley chinook salmon is to achieve naturally spawning population levels that support and maintain ocean commercial and ocean and inland recreational fisheries, and that fully use existing and restored habitats. This vision will contribute to the overall species diversity and richness of the Bay-Delta system and reduce conflict between protection for this species and other beneficial uses of water and land in the Central Valley.

This vision is consistent with restoring the Sacramento River winter-run chinook salmon to levels that will allow it to be removed from the State and federal endangered species lists; increasing populations of other chinook stocks to levels that eliminate any future need for protection under the State and federal Endangered Species Acts (ESAs); and providing population levels for all chinook stocks that sustain recreational and commercial fisheries and other scientific, educational, and nonconsumptive use of these valuable resources.

Within the broad context of ecosystem restoration, salmon restoration will include a wide variety of efforts, many of which are being implemented for other ecological purposes or which are not specific to chinook salmon. For example, restoring riparian woodlands along the Sacramento River between Keswick Dam and Verona will focus on natural stream meander, flow, and natural revegetational/successional processes. These factors will be extremely important in providing SRA habitat, woody debris, and other necessary habitats required by food organisms and juvenile and adult salmon populations.

Another example is to reactivate tidal flows into fresh and brackish (somewhat salty) marshes. Reactivating the tidal exchange in marshes will greatly increase the production of lower trophic organisms, thereby improving the foodweb. Reactivating tidal exchange will also substantially increase the complexity of nearshore habitats in the lower mainstem rivers, the Delta, and the Bay, which will be valuable habitats for juvenile salmon.

Operating the water storage and conveyance systems throughout the Central Valley for their potential ecological benefits can be one of the more important elements in restoring a wide spectrum of ecological resources, including chinook salmon.

Harvest management will play an important role in restoring healthy salmon populations. The Ecosystem Restoration Program Plan (ERPP) anticipates a highly compatible relationship between restoring ecological processes and harvest management recommendations. Ecological processes selected for restoration include those that create and maintain critical habitat elements. Harvest management recommendations focus on rebuilding naturally spawning stocks.

Lack of adequate corridors between upstream holding, spawning, and rearing habitat in certain tributary streams has impaired or reduced the reproductive potential of some stocks such as spring-run chinook salmon. Unscreened diversions are widespread in the Central Valley and are a known source of mortality to chinook salmon.

Many action-oriented activities are underway in the Central Valley that will assist in achieving the vision for chinook salmon. Some are short-term actions and some are long-term evaluations. All are designed to eliminate stressors and improve ecological processes and habitats.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

There are three major programs to restore chinook salmon populations in the Central Valley.

- Central Valley Project Improvement Act: The Secretary of the Interior is required by the Central Valley Project Improvement Act to double the natural production of Central Valley anadromous fish stocks by 2002 (USFWS 1995).

- Endangered Species Recovery Plan. The National Marine Fisheries Service is required under the federal ESA to develop and implement a recovery plan for the endangered winter-run chinook salmon and to restore the stock to levels that will allow its removal from the list of endangered species (NMFS 1996).

- Salmon, Steelhead Trout and Anadromous Fisheries Program Act: The California Department of Fish and Game (DFG) is required under State legislation (the Salmon, Steelhead Trout and Anadromous Fisheries Program Act of 1988) to double the numbers of salmon that were present in the Central Valley in 1988 (Reynolds et al. 1993).

Each of the major chinook salmon restoration/recovery programs has developed specific goals for Central Valley chinook salmon stocks. ERPP embraces each of the restoration/recovery goals and will contribute to each agency's program by restoring critical ecological processes, functions, and habitats, and reducing or eliminating stressors.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Chinook salmon are closely dependent on ecological processes and habitats and adversely affected by a variety of stressors.

Important ecological processes the directly influence the health of chinook salmon or its habitat include:

- Central Valley streamflows,
- Natural sediment supply,
- Stream meander corridors,
- Natural floodplain and flood processes,
- Central Valley stream temperatures,
- Bay-Delta hydraulics,
- Bay-Delta aquatic foodweb, and
- Upper watershed health and function.

Habitats used by chinook salmon during their juvenile or adult life stages include:

- Tidal perennial aquatic habitat,
- Delta sloughs,
- Midchannel islands and shoals,
- Saline and fresh emergent wetlands, and
- Riparian and riverine aquatic habitats.

Stressors that adversely affect chinook salmon or its habitats include:

- Water diversions,
- Dams, reservoirs, weirs, and other human-made structures,
- Levees, bridges, and bank protection,
- Dredging and sediment disposal,
- Gravel mining,
- Predation and competition,
- Contaminants,
- Harvest,
- Some aspects of artificial propagation programs, and
- Disturbance.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for chinook salmon is to ensure the recovery of the Sacramento winter-run chinook salmon, a species listed as endangered under the federal and California Endangered Species Acts (ESAs). Recovery of the winter-run chinook salmon would ensure overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of water in the Bay-Delta. The objective is also to ensure the restoration of Sacramento fall-run chinook, spring-run chinook, late-fall-run chinook, and San Joaquin fall-run chinook to support sustainable sport and commercial fisheries.

The overall target for chinook salmon is presented as a strategy to increase the survival and return of each generation. ERPP's approach is to contribute to managing and restoring each stock with the goal of maintaining cohort replacement rates of much greater than 1.0 while the individual stocks are rebuilding to desired levels. When the stocks approach the desired population goals, ERPP will contribute to maintaining a cohort replacement rate of 1.0. In practical application, management and restoration goals need to be developed on a stream-specific basis and include all runs of chinook salmon.

The strategy for achieving the chinook salmon vision includes protecting existing populations, restoring ecological processes, improving habitats, and reducing stressors. The following actions would improve chinook salmon populations:

- Restore ecological processes in the Central Valley. Chinook salmon are dependent on adequate streamflows; gravel recruitment, transport, and cleansing; low water temperatures; and channel configurations.

- Maintain adequate streamflows to improve gravel recruitment, transport, and cleansing; water temperatures; and channel conditions. Improved streamflow would also provide attraction flows for adult salmon migrating upstream to spawning grounds through the Bay, Delta, and lower rivers. Flows also support downstream transport for juvenile salmon migrating to the ocean and minimize losses to diversions and predators. Short-term improvements in flows may be possible with existing supplies. Necessary changes in streamflows may require long-term water supply improvements.

- Restore habitats required by chinook salmon. Where ecological processes cannot restore habitats to the desired level, habitats can be improved using direct measures. Important habitat components for chinook salmon include spawning gravel, water temperatures, and access to spawning habitats. In the short term, gravel can be introduced to rivers where needed. Fish passage facilities can be upgraded where deficient. Generally, habitat quality and availability along the lower reaches of the major rivers and in the Delta have been greatly diminished by the construction of levees; construction of levees that isolated rivers from their floodplains; and removal or other loss of riparian, shaded riverine, and woody debris habitats. A major long-term commitment will be required to restore the habitats in these areas.

- Protect existing populations in the Central Valley. The ERPP focuses on supporting efforts to protect existing natural populations of chinook salmon by limiting harvest of naturally spawned fish while emphasizing the harvest of hatchery-produced fish. A short-term action would be to evaluate mass marking of all hatchery-produced chinook salmon and limiting harvest to only marked salmon. Another short-term action would be to alter existing hatchery practices that do not embody the concepts of genetic conservation. A long-term action may involve restrictions on harvest gear, seasons, and fishing areas in commercial and sport fisheries.

- Eliminate stressors that cause direct or indirect mortality of chinook salmon. Important stressors on chinook salmon include insufficient streamflow, high water temperatures, blockages at diversion dams, predation near human-constructed structures, contaminants, unscreened diversions, and harvest. ERPP focuses on reducing each of these stressors in the short term and eliminating the conditions that bring about the stress factors in the long term by restoring natural processes and eliminating stressors where feasible.

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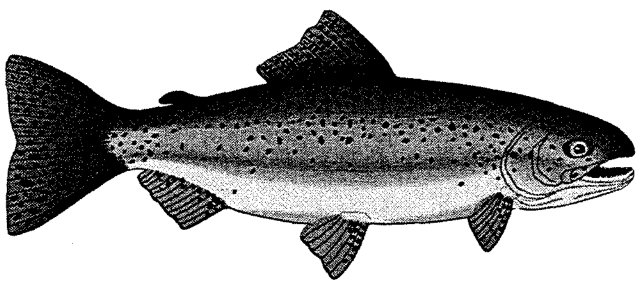


INTRODUCTION

Steelhead trout are an anadromous form of rainbow trout. This species spawns in freshwater, its juveniles rear in cool water for a year or more before migrating to the ocean. Steelhead spend one to three years in the ocean before maturing and returning inland to spawn. Because of their life cycle, young steelhead are susceptible to mortality resulting from water temperatures.

Annual counts of steelhead, taken at Red Bluff Diversion Dam, suggest that the recent spawning populations are less than 10,000 adult fish. This is a substantial decline from the estimated 30,000 fish that returned to Central Valley rivers and streams in the early 1960s (Mills et al. 1996, Mills and Fisher 1994).

RESOURCE DESCRIPTION

Rainbow trout exhibit one of the most complex life histories of any salmonid species. Those that exhibit anadromy (i.e., migrate as juveniles from fresh water to the ocean and then return to spawn in fresh water as adults) are called steelhead, and those that reside their entire lives in fresh water are called rainbow trout. Steelhead typically migrate to ocean waters after spending 1-3 years in fresh water. They reside in marine waters for typically 2 or 3 years before returning to their natal stream to spawn as 3- to 5-year-old fish. Unlike Pacific salmon, steelhead are iteroparous (i.e., they are capable of spawning more than once before they die). However, postspawning survival rates are generally low, thus the percentage of adults in the population that spawn more than once is low. It is likely that steelhead and resident forms interbreed, thus forming a single population in streams where they coexist.

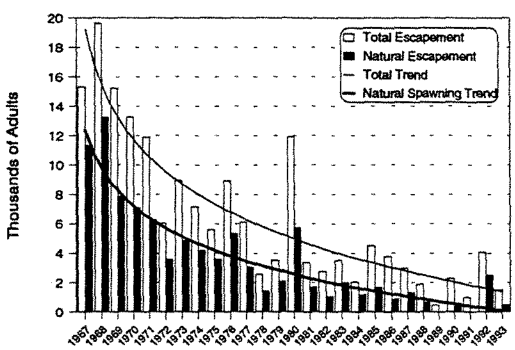
Biologically, steelhead can be divided into two reproductive ecotypes according to their state of sexual maturity at the time of river entry, the duration of their spawning migration, and behavior. These two ecotypes are termed "stream maturing" and "ocean maturing." Stream maturing steelhead enter fresh water in a sexually immature condition and require several months to mature and spawn. Ocean-maturing steelhead enter fresh water with well-developed gonads and spawn shortly thereafter. These two reproductive ecotypes are more commonly referred to by their season of freshwater entry (i.e., summer-run and winter-run steelhead). Central Valley steelhead stocks are typically of the ocean-maturing type and are called winter-run steelhead. Some evidence suggests that summer-run steelhead were once present but that construction of large dams on major tributaries, which would have blocked adults from reaching the deep pools they need to oversummer, most likely eliminated these populations.

The National Marine Fisheries Service (NMFS) has identified steelhead populations in the Central Valley as composing a single evolutionary significant unit (ESU). ESUs are defined using a variety of physical and biological data, including the physical environment (geology, soil type, air temperature, precipitation, riverflow patterns, water temperature, and vegetation); biogeography (marine, estuarine, and freshwater fish distributions); and life history traits (age at smolting, age at spawning, river entry timing, spawning timing, and genetic uniqueness).

The Central Valley steelhead ESU comprises the Sacramento and San Joaquin Rivers and their tributaries. Recent data from genetic studies show that samples of steelhead from Deer and Mill Creeks and Coleman National Fish Hatchery on Battle Creek are well differentiated from all other samples of steelhead from California.

In reviewing the status of Central Valley steelhead, NMFS concluded that ESU is in danger of extinction because of the widespread degradation, destruction, and blockage of freshwater habitats and the potential results of continuing habitat destruction, water allocation problems, and interactions between introduced and native stocks.

FIGURE 1. Sacramento River Steelhead
Adjusted Counts at Red Bluff Diversion Dam



Steelhead are somewhat unique in that they depend on essentially all habitats of a river system. Steelhead use the estuary for rearing and adapting to saltwater. The main channel is used for migrating between the ocean and upstream spawning and rearing areas. The tributaries are used for spawning and rearing. They are, therefore, found in virtually all ecological zones and many of their respective ecological units.

Overall, the decline of the steelhead trout population resulted from the cumulative effects of degrading habitats and environmental processes and functions. Constructing dams on the larger rivers and streams eliminated access to critical habitat for adults and juveniles. Excessively warm water temperatures during the prespawning, incubation, and early rearing period of juvenile steelhead; interrupting or blocking the free passage of juveniles and adults at diversion dams; losing natural emigration cues is attributable to altered flow regimes resulting from the export of water from large diversions in the south Delta. A large number of unscreened and poorly screened diversions entrain (capture) fish as they are migrating. Channelization, levee construction, and land use have led to degradation and loss of woody debris, shaded riverine aquatic, riparian corridors and forests, and floodplain functions and habitats.

A host of other factors has also contributed to the decline of the steelhead trout, but perhaps to a lesser degree. These include the various smaller water diversion facilities and dams; extensive loss of rearing habitats in the lower Sacramento River, San Joaquin River, and Sacramento-San Joaquin estuary through levee construction and marshland reclamation; and the interaction and predation by non-native species.

VISION

The vision for Central Valley steelhead trout is to achieve naturally spawning populations of sufficient size to support inland recreational fishing and that fully use existing and restored habitat areas. Achieving this vision will primarily require restoring degraded spawning and rearing habitats, enhancing fish passage to historic habitat, and supporting angling regulations consistent with steelhead trout population recovery. This vision is consistent with restoring populations of steelhead to levels that eliminate the need for any future protection under the State and federal Endangered Species Acts (ESAs). To achieve this vision, ecological functions and processes that create and sustain steelhead habitats would be maintained and restored and stressors and known sources of mortality would be reduced or eliminated.

The strategy for attaining this vision is to restore degraded spawning and rearing habitat in tributaries; restore access to historic habitat that is partially or completely blocked; support angling regulations consistent with restoring ecosystem processes and functions; support additional research to address large deficiencies in information regarding steelhead freshwater and ocean life history, behavior, habitat requirements, and other aspects of steelhead biology; and provide opportunities for angling and nonconsumptive uses.

In addition, the strategy includes operating Central Valley hatcheries to protect and maintain the existing genetic diversity of naturally spawning populations and provide hatchery-produced fish for a healthy recreational fishery.

NMFS has recommended general conservation measures for steelhead throughout their Pacific coast range. These conservation measures, when applied to the Central Valley, include the following:

- Implement land management practices that protect and restore habitat. Existing practices that may affect steelhead include timber harvest, road building, agriculture, livestock grazing, and urban development.

- Review existing harvest regulations to identify any changes that would further protect Central Valley steelhead.

- Incorporate practices to minimize impacts on native populations of steelhead into hatchery programs.

- Make provisions at existing dams to allow the upstream passage of adult steelhead.

- Provide adequate headgate and staff gage structures at water diversions to control and effectively monitor water usage, and enforce water rights.

- Screen irrigation diversions affecting downstream migrating steelhead.

Within the broad context of ecosystem restoration, steelhead restoration will include a wide variety of efforts, many of which are being implemented for other ecological purposes or which are not specific to steelhead trout. For example, restoration of riparian woodlands along the Sacramento River between Keswick Dam and Verona will focus on natural stream meander, flow, and natural revegetation/successional processes. These will be extremely important in providing shaded riverine aquatic habitat, woody debris, and other necessary habitats required by lower trophic organisms and juvenile and adult steelhead populations.

Operation of the Central Valley water storage and conveyance systems for their potential ecological benefits can be one of the more important elements in restoring a wide spectrum of ecological resources, including steelhead trout.

Inadequate connectivity between upstream holding, spawning, and rearing habitat in certain tributary streams has impaired or reduced the reproductive potential of some steelhead stocks. Providing stream flows, improving fish ladders, and removing dams will contribute to efforts to rebuild steelhead populations.

One critical effort will be to conduct the necessary evaluations and analyses to determine the potential benefits and consequences of reintroducing certain steelhead stocks above major dams to provide access to historic spawning and rearing areas. The potential transfer of adult fish above the dams may be straightforward, but the successful emigration downstream by juveniles cannot be ensured. Juvenile salmonid passage at large dams in the Columbia River basin has had little success and the viability of this option to protect and restore naturally spawning steelhead trout in the Central Valley is unknown.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Two major programs to restore steelhead trout populations exist within the Central Valley. The U.S. Fish and Wildlife Service's goal, as established by the Central Valley Project Improvement Act is to double the natural production of Central Valley anadromous fish stocks by 2002 (USFWS 1995). The California Department of Fish and Game is required under State legislation (The Salmon, Steelhead Trout and Anadromous Fisheries Program Act of 1988) to double the numbers of steelhead estimated to have been present in the Central Valley in 1988 (McEwan and Jackson 1996, Reynolds et al. 1993, and McEwan and Nelson 1991).

Each of these steelhead trout restoration programs has developed specific restoration goals for Central Valley steelhead trout stocks. Implementation of the steelhead vision strategy will contribute to each agency's program through the restoration of critical ecological processes and functions, restoration of habitats, and reduction or elimination of stressors.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Steelhead trout are closely dependent on ecological processes and habitats and adversely affected by a variety of stressors.

Important ecological processes the directly influence the health of steelhead trout or its habitat include:

- Central Valley streamflows,
- Natural sediment supply,
- Stream meander corridors,
- Natural floodplain and flood processes,
- Central Valley stream temperatures,
- Bay-Delta hydraulics,
- Bay-Delta aquatic foodweb, and
- Upper watershed health and function.

Habitats used by steelhead trout during their juvenile or adult life stages include:

- Tidal perennial aquatic habitat,
- Delta sloughs,
- Midchannel islands and shoals,
- Saline and fresh emergent wetlands, and
- Riparian and riverine aquatic habitats.

Stressors that adversely affect steelhead trout or its habitats include:

- Water diversions,
- Dams, reservoirs, weirs, and other human-made structures,
- Levees, bridges, and bank protection,
- Dredging and sediment disposal,
- Gravel mining,
- Predation and competition,
- Contaminants,
- Harvest, and
- Artificial propagation programs.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for steelhead trout is to ensure the recovery of this species, which is proposed for listing under the federal Endangered Species Act (ESA), to sufficient population size to support inland recreational fishing and fully use existing and restored habitat areas in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of water in the Bay-Delta.

The short-term approach for restoring steelhead populations is to support the management and restoration of each stock to maintain the to the adult population at a ratio much greater than 1.0 while the individual stocks are rebuilding to desired levels. Recruitment rates greater than 1.0 indicate that the number of young fish reaching adulthood exceeds the size of the parental population that produced them.

The long-term approach is to contribute to maintaining cohort replacement rates at 1.0 when the stocks approach the desired population goals.

The following actions would help to achieve the short- and long-term restoration of Central Valley steelhead populations:

- Implement a coordinated approach to restore ecosystem processes and functions.
- Implement measures to restore habitat when restoration of ecosystem processes and functions is not feasible.
- Protect spawning and rearing habitat in upper tributary watersheds.
- Improve riparian corridors in lower tributaries and rivers.
- Improve estuary habitat.
- Manage and operate the four hatcheries in the Central Valley that propagate steelhead in order to protect the genetic diversity of naturally and hatchery produced stocks.
- Provide sufficient flows in lower tributaries for immigration and emigration to improve migration success.
- Reduce losses to unscreened diversions.
- Reduce fish mortality in the recreational fishery.
- Implement programmatic actions proposed in the 14 ecological zone visions to help achieve steelhead targets by creating and sustaining improved habitat conditions and reducing sources of mortality.

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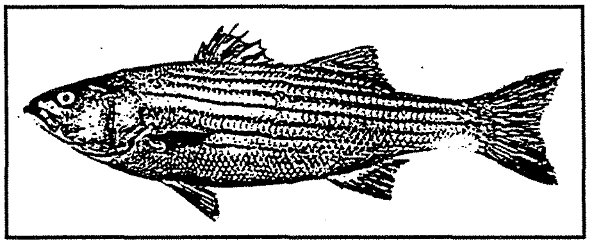


INTRODUCTION

The striped bass is an important non-native anadromous sport fish with high recreation value. It also plays an important role as a top predator in the Bay-Delta and its watershed. Striped bass is an important element of the ecosystem for several reasons and guidance in developing recommendation for this species originates from the ecosystem quality goal and objectives. The goal of the ecosystem program is:

- *Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species.*

The ecosystem objectives are:

- (A) *Improve and increase aquatic habitats so that they can support the sustainable production and survival of native and other desirable estuarine and anadromous fish in the estuary*,
- (B) *Improve and increase important wetland habitats so that they can support the sustainable production and survival of wildlife species*, and
- (3) *Increase population health and population size of Delta species to levels that assure sustained survival including increasing population of economically important species.*

Major factors that limit striped bass contribution to the health of the Delta are streamflow, water diversions, spawning and rearing habitat, legal and illegal harvest, predation and competition from non-native fishes, and reduce survival from contaminants in the water.

RESOURCE DESCRIPTION

Striped bass were introduced into the Bay-Delta from the east coast of the United States in 1879. For the past century, they have been an important sport fish, commercial fish, and top predator within the Bay-Delta and upstream rivers. They adapted well to the complex habitat conditions of the estuary and remain the premier sport fish of the Bay and Delta. Anglers seek out striped bass along the coast, in the Bay and Delta, and in the lower portions of the Sacramento and San Joaquin Rivers and their tributaries. Striped bass are also an important recreational resource in the waterways of the State and federal water projects south of the Delta.

In the Sacramento River, striped bass are commonly found from Princeton downstream to the Delta and in the lower Feather and American Rivers. In the San Joaquin basin, they are found in the lower Stanislaus, Tuolumne, and San Joaquin Rivers. Striped bass spawn primarily in the Sacramento River between Colusa and Sacramento and in the San Joaquin River portion of the Delta.

Juvenile rearing habitat include sloughs, river channels, and bays of the western Delta and Suisun Bay. In wet years young fish rearing habitat extends into San Pablo Bay and adjacent tidal sloughs and marshes. Yearling striped bass are found throughout the Bay and Delta. Adult striped bass are widely distributed from the ocean to the rivers.

The number of adult striped bass and young produced each year have declined dramatically over the past several decades. The total adult population has declined from about 3 million fish in the 1960s to 1.5 million in the early 1970s. More recent estimates are 500,000 to 700,000 adult fish. A greater decline has occurred in older fish, possibly the consequences of greater numbers of older fish migrating to coastal waters, or higher mortality of individual adults from contaminants in the water.

The decline in the adult population of striped bass has been accompanied by a decline in the production of young. The young bass abundance index for summer, when they are 1.5 inches long, has declined dramatically, especially during the recent drought of the late 1980s and early 1990s, and has not recovered. Factors related to and believed to contribute to this decline include the following:

- Low spring flows in the Sacramento River are believed to reduce survival of eggs and larvae by creating poor water quality conditions, reducing plankton food supply, and increasing vulnerability to water diversions.
- Low freshwater flows through the Delta and Suisun Bay may limit the production of food organisms during critical early life stages of striped bass.
- Low Delta outflow may limit transport of eggs, larvae, and juvenile striped bass into quality nursery grounds of Suisun Bay and away from water diversions in the Delta.
- Higher transport of Sacramento River water across the Delta toward the south Delta pumping plants moves more striped bass young into areas where they are more susceptible to entrainment into agricultural diversions or water project export pumps.

The number of juveniles lost at south Delta export facilities was in the tens of millions in some years during the 1960s to mid-1970s, and again in the middle to late 1980s. The estimated loss in 1974 exceeded 100 million juveniles. Although subsequent export losses have decreased, the rate of loss per unit of population has greatly increased as population abundance has declined.

The number of adult spawners has dropped to such low levels in recent years that there may no longer be sufficient eggs spawned to bring about quick recovery in the population. Good juvenile production even when flows and habitat are excellent for survival is limited by reduced adult spawning populations.

In addition to the low survival of young fish and their low entry into the adult spawning population, mortality rates of adults have increased despite reduced harvest rates in the sport fishery. The higher mortality rates are particularly evident in older adults, and may be a result of effects of toxins, poaching, marine mammal predation, or combinations of these and other factors.

Other factors possibly contributing to the decline and low abundance of striped bass include toxins that reduce survival of young bass or their food supply, competition or predation by recently established, non-native fishes, such as gobies, or poor food production caused by the influx of Asia clams. Both the gobies and Asia clams were introduced from ballast water released from ships from Asia.

VISION

The vision for striped bass is to restore populations to their 1960s level of abundance to support a sport fishery in the Bay, Delta, and tributary rivers, and to reduce the conflict between protection of striped bass and other beneficial uses of water in the Bay-Delta.

Over the past two decades, a major focus of striped bass recovery efforts has been Delta outflow enhancement and restrictions on spring and early summer water exports. The recent 1995 Water Quality Control Plan provided interim provisions for improving spring Delta outflows and limiting exports, but did not address summer outflows or effects of water exports in summer or fall. This vision anticipates further improvements in the following:

- spring Delta inflows and outflows in drier years when more flow is needed for successful spawning,
- Bay-Delta foodweb production,
- transporting egg and larval striped bass to nursery grounds in Suisun Bay,
- reducing the effects of water exports from the Delta, especially exports that reverse the natural flow patterns in the Delta.

Although deterioration of habitat may not be a major factor in the decline of striped bass, it could be an important detriment to their recovery. Protecting, improving, and restoring a substantial amount of shallow-water habitat in the Bay and Delta may improve the food supply for striped bass, as well as provide more area for rearing juvenile striped bass. An improved food supply and increased rearing area may help overcome other factors that have little potential for change (e.g., predation and competition from non-native species). Increases in tidal wetlands will provide tidal channels that are important rearing habitat for juvenile striped bass. Improvement and restoration of shallow waters and riparian vegetation along levees and channel islands in the Delta may provide further important habitat for young striped bass. Habitat improvements are expected to also increase the abundance of shrimp and small fish that are important prey of young and adult striped bass and may lead to higher striped bass survival rates.

Reducing the extent and effect of stressors on striped bass will also be important to their recovery. Reducing losses of young striped bass at water diversions in the Delta and Bay, particularly the very high losses at the south Delta pumping plants of the State and federal water projects, will be most important. Improvements are needed to upgrade the two fish protection facilities to reduce the loss of young bass to entrainment into the pumping plants, and to reduce indirect losses to predators associated with the fish protection facilities. Pumping plant operations could also be reduced during periods of high losses.

Longer term actions may involve relocating the pumping plant intakes, screening or reducing the number of small water diversions to agricultural lands in the Delta, and continuing to find ways to reduce entrainment losses into cooling water diversions at two power plant complexes in the Delta. Limiting further introductions of non-native species and reducing the input of contaminants into Central Valley waterways may also be important to striped bass recovery. In the short-term, recovery may depend on supplementing natural reproduction with hatchery and pen-reared striped bass, and possibly reducing illegal and legal harvest. Management actions for striped bass need to be carefully evaluated and structured to avoid adverse affects on native species.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore striped bass in the Central Valley would involve cooperation and support from other programs underway to restore striped bass and other important fish.

- The Central Valley Project Improvement Act (CVPIA) calls for implementing changes in flows and project facilities and operations by 2002 that lead to doubling of the striped bass population.

- The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 requires the DFG to restore striped bass in the Central Valley.

- The State Water Resources Control Board will implement the Water Quality Control Plan for the San Francisco/Sacramento-San Joaquin Delta estuary that will include provisions to limit entrainment in diversions and protect habitat conditions for Sacramento splittail, chinook salmon, striped bass, and other species.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Because striped bass are predators, they could affect efforts to recover populations of a number of native fishes of the Central Valley including chinook salmon, steelhead, delta smelt, longfin smelt, and Sacramento splittail. Consequently, it will be necessary to consult and cooperate with the National Marine Fisheries Service and U.S. Fish and Wildlife Service under the federal Endangered Species Act (ESA) and DFG under the California ESA.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

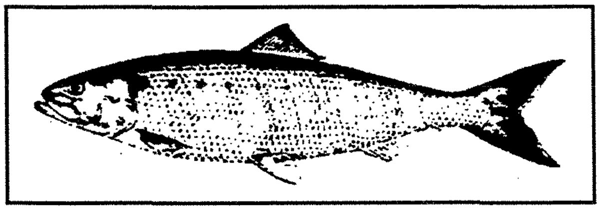
The implementation objective for striped bass is to restore its population levels to those of the 1960s to contribute to a recreational fishery in the Bay-Delta . Increased population levels of striped bass would reduce conflict between the need for its protection and other beneficial uses of water in the Bay-Delta.

General targets for striped bass are:

- restore population to levels of the 1960s,
- maintain flow in the Sacramento River at Sacramento at 13,000 cfs in the spring,
- improve health of average individual striped bass in population,
- reduce the rate of illegal harvest of striped bass, an
- reduce the percentage of young striped bass lost to entrainment at water diversions.

General programmatic actions which will help to meet the targets for striped bass include:

- protect and restore shallow water, tidal slough, and wetlands habitats,
- improve aquatic foodweb,
- maintain 13,000 cfs flow in lower Sacramento River in the spring months of all but driest years,
- increase Delta outflow in spring of dry and below normal years,
- reduce the introductions of non-native aquatic organisms into the Bay-Delta,
- improve water quality of the Bay-Delta,
- provide greater enforcement to reduce illegal harvest,
- reduce losses of eggs, larvae, and juvenile striped bass at water diversions,
- upgrade fish protection facilities at south Delta pumping plants and power generation plants in the Delta, and
- supplement striped bass population with pen-reared and hatchery-reared striped bass as needed until natural production is adequate to sustain the population at target level.



INTRODUCTION

American shad is an important non-native anadromous sport fish with high recreational value. It migrates in spring from the ocean into the Bay-Delta and upstream to spawn in Central Valley rivers. Newly hatched young spend their first summer in the rivers and Delta before migrating downstream to the ocean in fall. American shad is an important element of the ecosystem for several reasons and guidance in developing recommendation for this species originates from the ecosystem quality goal and objectives. The goal of the ecosystem program is:

- *Improve and increase aquatic and terrestrial habitats and improve ecological functions in the Bay-Delta to support sustainable populations of diverse and valuable plant and animal species.*

The ecosystem objectives are:

- (A) *Improve and increase aquatic habitats so that they can support the sustainable production and survival of native and other desirable estuarine and anadromous fish in the estuary,*
- (B) *Improve and increase important wetland habitats so that they can support the sustainable production and survival of wildlife species*, and
- (3) *Increase population health and population size of Delta species to levels that assure sustained survival including increasing population of economically important species.*

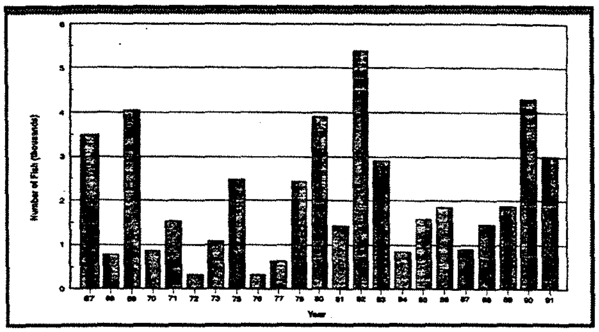
Major factors that limit the contribution of the American shad to the health of the Delta are streamflow, aquatic habitat, and food supply.

RESOURCE DESCRIPTION

The American shad was introduced into Central Valley rivers from the east coast in the 1870s and 1880s. It adapted well to the complex habitat conditions of the rivers and estuary. It continues to be an important sport fish in the Sacramento, Feather, Yuba, and American Rivers and has extended its range as far north as the Columbia River. Adults (age 3-5) migrate into the rivers from the ocean to spawn from late April through June. Some may remain in the rivers through August before returning to the Bay-Delta and ocean. Many die during the spawning run, but about 30% of the runs are made up of repeat spawners. In the Sacramento River system, American shad are commonly found from Red Bluff downstream to the Delta and in the lower Feather, Yuba, and American Rivers. American shad populations are small in the San Joaquin basin compared with those in the Sacramento basin.

When the adult population was measured in 1976 and 1977, the total Central Valley run was estimated at 3 million and 2.8 million, respectively. The California Department of Fish and Game (DFG) has conducted annual fall midwater trawl surveys in the Delta since 1967 to monitor trends in the population's health. Juvenile shad catch has generally been higher in wetter years (1967, 1969, 1975, 1978, 1980, 1982, and 1983) and lower in dry years (1968, 1972, 1976, 1977, 1984, and

1987). The production index was relatively high, however, in two recent dry years (1990 and 1991).



Index of Juvenile American Shad Abundance in Fall Midwater Trawl Survey

Ocean, estuary, and river conditions affect overall shad abundance. Growth and survival in the ocean may be affected by El Niño (ocean warming). Water temperatures and flows are important habitat factors in the spawning rivers of the Central Valley. River flows trigger the shad to move into rivers and affect their selection of spawning locations among and within the rivers. Water temperatures determine the onset of spawning (59-68°F). High water temperatures (above 68°F) may reduce adult survival. Factors believed to affect American shad production in the Central Valley include the following:

- Low flows in spring may delay or hinder shad from moving into the rivers to spawn. During their upstream migration through the Delta, adult shad may delay spawning or may die because of the higher water temperatures resulting from low flows. Low flows also may reduce downstream transport of eggs and larvae to productive nursery areas.

- Transport of Sacramento River water south across the Delta and toward the south Delta pumping plants may carry more American shad young into the southern Delta and away from their primary migration path to the ocean. Under low Delta outflow, shad young may be more susceptible to loss at agricultural diversions and water project export pumps. Annual losses of juveniles at south Delta export facilities reach into the millions.

- Poor water quality and low spring flows may limit production of American shad in the San Joaquin River and its tributaries.

- Diversion dams on valley rivers limit American shad from moving into potential spawning reaches. Examples include the Red Bluff Diversion Dam on the Sacramento River, Daguerre Dam on the Yuba River, and Woodbridge Dam on the Mokelumne River. Shad are generally unable to use the fish ladders provided at these diversion dams.

- Pollutants may affect the production and run size of American shad by reducing survival of young and their food supply.

Harvest rates of adult shad in the sport fishery are low and have little impact on production of American shad.

VISION

The vision for American shad is to maintain a naturally spawning population that supports a sport fishery similar to the fishery that existed in the 1960s and 1970s. Achieving this vision will reduce the conflict between protection of this species and other beneficial uses of water in the Bay-Delta.

A major focus of Central Valley fish recovery efforts over the past two decades has been on flow enhancement in streams and rivers. Natural river flows in dry and normal water-year types has been reduced, particularly in spring, by water development in the Central Valley. The 1995 December Delta Accord provided interim provisions for improving spring flows. Further improvements are anticipated under the Central Valley Project Improvement Act (CVPIA).

The restoration of American shad vision requires further improvements in drier years when more flow is needed to attract American shad to upstream spawning areas in the rivers and major tributaries, including the American, Feather, and Yuba Rivers, and to transport egg and larval shad to nursery grounds in the lower rivers and Delta.

Habitat improvements could contribute to increases in American shad runs. Protecting, improving, and restoring shallow-water habitat in rivers and the Delta may improve the food supply for American shad and provide better rearing habitat. Improved food supply and rearing habitat may help to overcome other factors that are unlikely to change (e.g., the presence of competing non-native species).

Reducing the extent and effect of stressors will further benefit American shad runs. Most important will be reducing loss of young American shad at water diversions in rivers and the Delta, especially large losses at the south Delta pumping plants of the State and federal water projects. The two fish protection facilities should be upgraded to reduce entrainment of young American shad in the pumping plants and the concentrations of predators associated with the fish protection facilities. Screening or reducing the number of the many small water diversions to agricultural lands in the Delta may also provide benefits. Limiting further introduction of non-native species and reducing the input of toxic pollutants into Central Valley waterways will also provide benefits.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to maintain American shad runs in Central Valley rivers would involve cooperation and support from other established programs underway to restore American shad and other important fish.

- CVPIA (PL 102-575) calls for doubling the American shad population by 2002 through changes in flows and project facilities and operations.

- The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988 DFG is required under State legislation to restore American shad in the Central Valley.
- The Lower American River Task Force and Water Forum will improve flows and habitat in the lower American River that will benefit American shad.

- The State Water Resources Control Board will implement the Water Quality Control Plan for the San Francisco/Sacramento-San Joaquin Delta estuary that will include provisions to limit entrainment in diversions and protect habitat conditions for Sacramento splittail, chinook salmon, striped bass, and other species.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Actions to restore populations of salmon, steelhead, striped bass, and Delta native fishes are likely to benefit the runs of American shad.

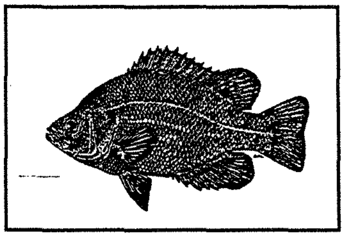
IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for American shad is to maintain naturally spawning populations that support sport fisheries similar to fisheries that existed in the 1960s and 1970s to contribute to the recreational use of the Bay-Delta. Meeting this objective would reduce conflict between the need for protection of this species and other beneficial uses of water in the Bay-Delta.

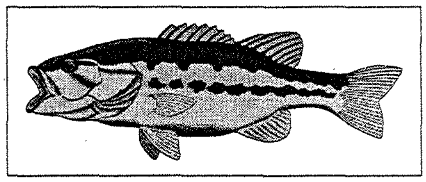
The general target for American shad is to improve production of young, particularly in dry years as measured in the DFG fall mid-water trawl survey.

Programmatic actions that would help improve American shad populations in Central Valley rivers include the following:

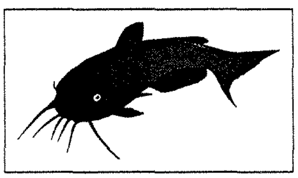
- Provide additional Sacramento, Feather, Yuba, and American River flows in spring of dry and normal water years to attract adult spawners and transport young downstream to productive nursery habitat.
- Remove barriers to American shad migrations in the Sacramento, Yuba, and Mokelumne Rivers.
- Reduce adverse effects of water diversions on American shad in fall.
- Allow the first natural pulse of flow in the fall to pass through the Delta to the Bay to help juvenile American shad migrate to the ocean.
- Upgrade existing fish protection facilities at south Delta pumping plants of the Central Valley Project and the State Water Project.
- Reduce the number, screen or upgrade screening, or relocate diversions that entrain American shad in the rivers and Bay-Delta.



Sacramento Perch



Largemouth Bass



White Catfish

INTRODUCTION

Native resident fish species of the Delta are important ecologically and as indicators of ecosystem health. Some, such as the tule perch, Sacramento sucker, and threespine stickleback, are important elements of the Bay-Delta foodweb. Other, such as the Sacramento squawfish, are important predators. Native resident fishes have declined as a percent of the total fish species abundance of the Bay-Delta and its watershed.

Non-native resident fishes include many species introduced to improve the foodweb and sport fishing including threadfin shad, white catfish, and largemouth bass. Others, such as the yellowfin goby, have been accidently introduced in the ballast water of ships. While some species are considered desirable, other are undesirable because they compete with or prey upon desirable native and non-native fish. The wagasagi, or pond smelt, a close relative of the delta smelt introduced by DFG to improve the foodweb of foothill reservoirs, now potentially threatens the delta smelt population through interbreeding and competition.

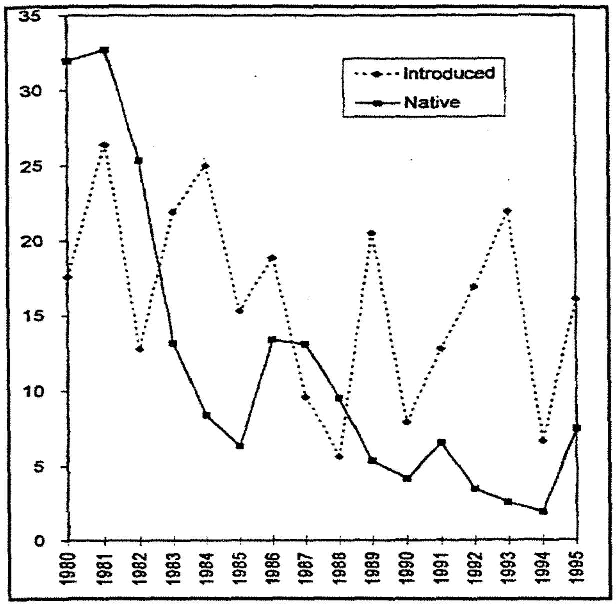
Factors contributing to the decline of some important resident species include predation and competition of non-native species, loss and degradation of habitat, poor foodweb productivity, losses to water diversions, and reduced survival from exposure to toxins in the water.

RESOURCE DESCRIPTION

Resident species compose the bulk of species found in fresh and low-salinity water (i.e., less than 4 parts per thousand [ppt] salinity) of the Sacramento-San Joaquin Delta estuary. Resident species represent an important component of sport catch (e.g., white catfish, largemouth bass, and bluegill); the historical native fish fauna (e.g., tule perch, Sacramento blackfish); and forage fish (e.g., threadfin shad).

As with other Delta species, the habitat of resident fishes has been greatly diminished by human-caused actions. Increased habitat and expanded distribution and abundance of resident species can be realized through restoring habitat together with improving natural ecological processes and functions.

Spawning and rearing habitat includes shallow edgewaters bordered by healthy riparian and aquatic plants that provide protective, food-rich environments. Productive edgewater habitats are currently very limited in the Delta. Many resident Delta species inhabit shallow areas that have structural diversity provided by riparian and aquatic vegetation. Levee construction in the 1800s created narrow channels and eliminated vast areas of tule marsh, areas most likely



Index of Native and Introduced Fishes in Suisun Marsh Trawl Survey

important as spawning and rearing habitat for Delta species. Levee maintenance programs that remove riparian vegetation and dredging continue to reduce the quality of shallow water habitat used by resident species. Erosion caused by increased flow velocity, changes in channel structure, and boat wakes continues to reduce remnant riparian, marsh, and channel island habitats. Water hyacinth and other exotic aquatic plants now clog many sloughs that are important habitat of resident fish.

Losses to Delta diversions (e.g., hundreds of small agricultural diversions, Central Valley Project [CVP] and State Water Project [SWP] export pumps, and Pacific Gas & Electric [PG&E] power generation facilities) may reduce resident species abundance through direct entrainment or indirect effects on the prey of resident fish. Large numbers of some resident species (e.g., white catfish, threadfin shad) are entrained in Delta diversions. Other resident species (e.g., largemouth bass) spend their lives in habitat that is in close proximity to where they were spawned and are not particularly susceptible to entrainment in Delta.

Food availability, toxic substances, and competition and predation are among the factors influencing abundance of resident species. In addition, harvest of many resident species for food and bait by sport anglers may affect abundance.

VISION

The vision for resident fish species is to maintain and restore the distribution and abundance of native species, such as Sacramento blackfish, hardhead, tule perch, and Sacramento perch; and non-native species, such as white catfish, largemouth bass, and threadfin shad, to support a sport fishery and healthy nongame fish populations. Although the Sacramento perch no longer occurs in the Delta, it is included with resident native species because actions to maintain and restore other resident species populations would benefit Sacramento perch in the event they are reintroduced to the Delta.

Ecosystem processes are closely tied to habitat restoration needs and actions. Resident species would benefit from conditions to maintain productivity and suitability of spawning and rearing habitat (including production of food). Actions to rehabilitate ecosystem processes include: changing Delta configuration, facility operations (including Delta diversions and channel barriers and gates), and Delta inflow and outflow.

Stressor reduction is a major component of restoration and maintenance of resident species populations. A primary concern with regard to vulnerable species is the reduction of losses to diversions. Actions to reduce losses include upgrading existing fish protection facilities, installing fish screens on currently unscreened facilities, removing predators associated with diversions and fish protection facilities, relocating and consolidating existing diversions, changing seasonal timing of diversions, and reducing the number of diversions. Resident species would also benefit from actions to reduce pollutant input to streams and rivers in the Sacramento-San Joaquin River basin and may benefit from actions to prevent introduction of non-native species that would prey upon or compete with native species for habitat and food supply.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore and maintain resident species would involve cooperation and support from other established programs that protect and improve conditions for delta smelt, striped bass, and other species.

- The Recovery Plan for the Sacramento/San Joaquin Delta native fishes will be considered in the development of actions.

- Central Valley Project Improvement Act will implement actions that will benefit resident species, including changing the timing of diversions and restoring habitat.

- The State Water Resources Control Board will implement the Water Quality Control Plan for the San Francisco/Sacramento-San Joaquin Delta estuary that will include provisions to limit entrainment in diversions and protect habitat conditions for Sacramento splittail, chinook salmon, striped bass, and other species.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration efforts relating to resident fish will be closely tied with efforts for delta smelt, longfin smelt, and splittail.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for resident fish species is to maintain and restore the distribution and abundance of resident native fish species, such as Sacramento blackfish, hardhead, tule perch, and Sacramento perch, and non-native species, such as white catfish, largemouth bass, and threadfin shad, to support a sport fishery and healthy forage populations.

The target for resident fishes is to increase their abundance indices in the DFG fall midwater trawl survey and Suisun Marsh Trawl Survey to historical levels (e.g., 20 units or higher in the Suisun marsh Trawl survey).

Resident species would benefit from the following general restoration activities:

- adding and modifying physical habitat,

- breaching levees to inundate existing islands,

- setting levees back to increase shallow-water habitat along existing channels,

- restoring riparian areas,

- protecting existing shallow-water habitat from erosion,

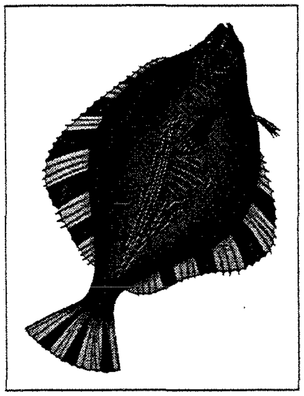
- filling relatively deep water areas with sediment to create shallow-water habitat,

- eliminating water hyacinth and other noxious aquatic plants from Delta channels and sloughs,

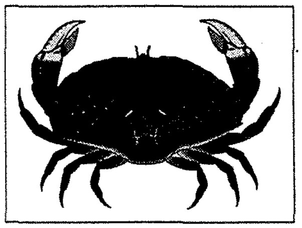
- upgrading existing fish protection facilities at South Delta pumping plants,

- installing screens on unscreened diversions,

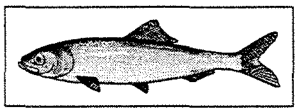
- removing predators at diversions,
- relocating or consolidating diversions,
- reducing concentrations of toxins in Bay-Delta waters, and
- preventing further introductions of non-native aquatic organisms.



Starry Flounder



Dungeness Crab



Pacific Herring

INTRODUCTION

Marine fishes include many species that are abundant and important ecologically in the Bay and coastal waters. Two ecologically important species are the Pacific herring and northern anchovy, whose young are important in the foodweb as prey of salmon, sturgeon, and striped bass, as well as other fish and waterfowl such as cormorants and terns. Pacific herring, Dungeness crab, and Bay shrimp also support commercial fisheries. Starry flounder contribute to the local Bay-Delta sport fishery. The Bay and Delta are essential spawning and nursery areas for many marine fish and invertebrates found in the Bay and coastal waters.

Factors that affect the survival and production of marine fish and invertebrates in the Bay-Delta include Delta outflow, water diversions, foodweb productivity, availability and quality of shallow water and wetland habitats, and water quality.

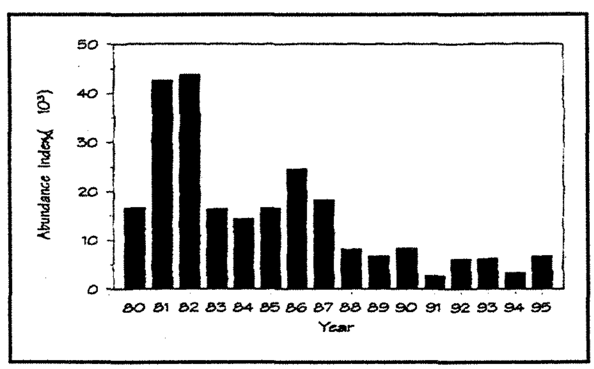
Improvements in production and survival of marine and estuarine fishes in the Bay and Delta will provide ancillary benefits to important estuarine, anadromous, and resident fishes of the Bay-Delta.

RESOURCE DESCRIPTION

There are many species of marine/estuarine fish and larger invertebrates that live in and depend on the Bay or Delta for at least a portion of their life cycles. Some of these are important contributors to the ecological health and well being of estuarine, freshwater, and anadromous fish that inhabit the Bay-Delta. Some, such as the Pacific herring, northern anchovy, starry flounder, shiner perch, Dungeness crab, and bay shrimp, depend at least partially on the Bay-Delta as a nursery for young. At times, some of these species are among the most abundant in the Bay-Delta and are essential elements of the foodweb that supports important fish such as chinook salmon, white sturgeon, and striped bass.

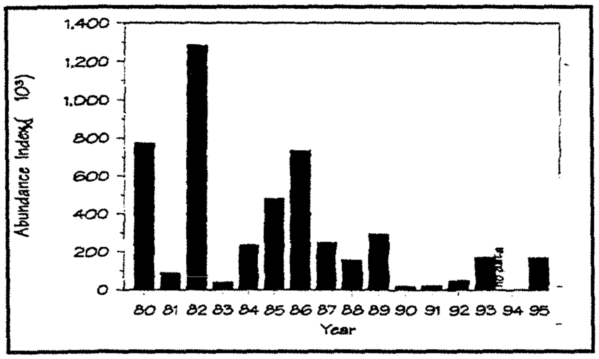
The abundance of starry flounder, Pacific herring, bay shrimp, shiner perch, and other species appears related to the amount of freshwater outflow to the Bay. Freshwater outflow contributes to food production, estuarine flow patterns, habitat conditions, and water quality. While some species, such as the Pacific herring, spawn in the Bay, others spawn in the ocean and their young migrate into the Bay and Delta, aided by tidal and gravitational currents.

The abundance of starry flounder, Pacific herring, bay shrimp, and shiner perch as measured in California Department of Fish and Game (DFG)

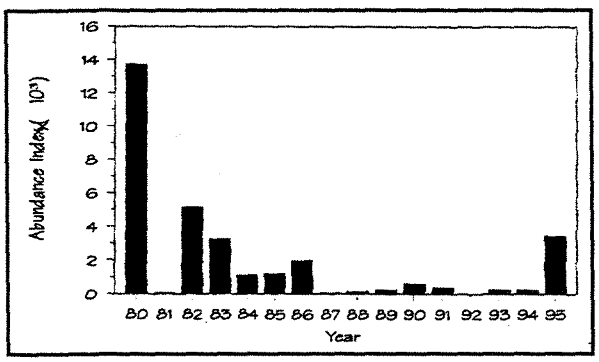


Index of Young Shiner Perch from DFG Bay Trawl Survey

Bay trawling surveys declined during the 1987-1992 drought; some recovery was evident by 1995. Generally, low abundance occurred in drier years, with this pattern particularly apparent for bay shrimp, starry flounder, and Pacific herring. For most of the marine/estuarine species, factors relating to the marine environment are also important and effects are difficult to separate from estuary factors.



Index of Young Pacific Herring from DFG Bay Trawl Survey



Index of Young Starry Flounder from DFG Bay Trawl Survey

Low abundance of marine/estuarine species has occurred along with a number of other changes in the estuary that could be a factor in suppressing populations. Factors related and believed to contribute to low marine/estuarine fish abundance in the Bay-Delta include the following:

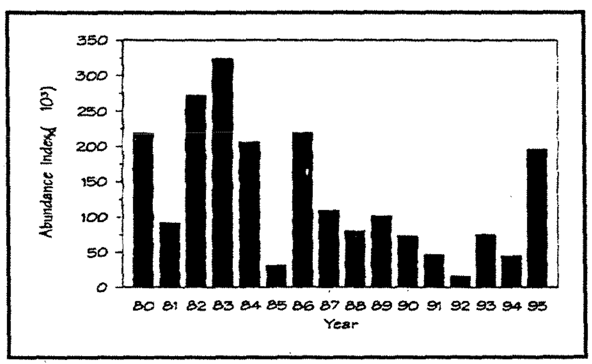
- Low outflows in late winter and spring are believed to reduce movement of young marine/estuarine fish into the Bay and Delta. This would reduce foodweb production, which affects the survival and production of marine/estuarine fish. Low flows are a consequence of low rainfall and more precipitation falling as winter rains than as snow and limited winter and spring runoff in dry and normal years being held in basin storage reservoirs.

- Low Delta outflows limit transport of larvae and juveniles upstream into the Delta from the Bay by limiting estuarine circulation. (Higher Delta outflow of freshwater on the surface, provides greater up-estuary transport of marine waters along the bottom.)

- Loss of larvae and juveniles into water diversions in Suisun Bay, Suisun Marsh, and the Delta may reduce production, especially in drier years when the percentage of freshwater diverted is sharply higher than that in wetter years.

- Toxic water and sediment may also reduce the survival of marine/estuarine fish in the Bay and Delta. The effect may be indirect through poor plankton food supply or direct through egg, larvae, or juvenile poisoning.

Other factors possibly contributing to the reduced abundance of marine/estuarine fish and large invertebrates include competition or predation by recently established non-native fishes. Two of the dominant non-native species, gobies and Asia clams, were introduced from ballast water of ships from Asia. Changes in the plankton foodweb from non-native species may also be contributing to the decline.



Index of Immature Bay Shrimp in DFG Bay Trawl Survey

VISION

The vision for marine/estuarine fishes is to restore populations to levels that existed in the early 1980s through restoration of habitat and aquatic foodweb, and improvements in winter-spring Delta outflow.

A major focus of recovery efforts should be on enhancement of freshwater outflow in late winter and spring of dry and normal water-year types. Natural Delta outflows in dry and normal water-year types have been reduced particularly in late winter and spring. Such flows are coincident with the occurrence and productivity of marine/estuarine fish and large invertebrates in the upper Bay and Delta. The 1995 December Accord provided interim provisions for improving February-June Delta outflows. Further improvements are needed in Delta outflows in late winter and spring in drier years, when more flow may be necessary to sustain a high abundance of marine/estuarine fish in San Pablo and Suisun Bays.

Habitat restoration could play an important part in maintaining marine/estuarine fish and large invertebrates abundance and ecological role in the Bay and Delta. Protecting, improving, and restoring considerable shallow-water habitat (tidal wetlands) in the Bay and Delta will improve the food supply for marine/estuarine fish and provide more rearing area. The improved food supply and rearing habitat area may help overcome other factors that have little potential for change (e.g., non-native species).

Increases in tidal wetlands will provide tidal channels that are important rearing habitat for many of the marine/estuarine species. Habitat improvements should also increase the abundance of plankton food for marine/estuarine species. A greater abundance of plankton will lead to improved survival of larvae and juveniles and increase the available food supply for such important species as chinook salmon, sturgeon, and striped bass.

Reducing the extent and effect of stressors will be critical to maintaining high seasonal population levels of marine/estuarine fish in the Bay and Delta.

Restoring marine/estuarine fish to healthy levels in the Bay and Delta will allow these species to serve their ecological role in the foodweb of the estuary. Their restoration will require a multifaceted approach of flow enhancement, habitat improvements, and stressor reductions.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to maintain a high abundance of marine/estuarine fish and large invertebrates in the Bay would also involve cooperation and support from other established programs to restore habitat and fish populations in the basin.

- Water Quality Control Program for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (May 1985) and Water Right Decision 1485 (1978).

- The Central Valley Project Improvement Act (PL 102-575): This program involves actions that may directly or indirectly benefit marine/estuarine fish populations in the Bay and Delta.

- The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988).

- The California Department of Fish and Game is required under State legislation to restore numbers of anadromous fish in the Central Valley. Actions include restoring the food supply of anadromous fish; that food supply includes marine/estuarine fish.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration of marine/estuarine fish and invertebrate populations is integrally linked with restoration of Delta outflow, tidal wetlands, and aquatic foodweb, and reductions in stressors including water diversions, contaminants, and non-native species introductions to the Bay-Delta.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

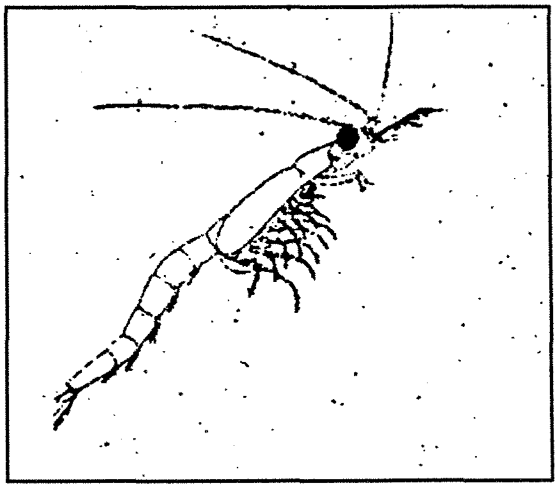
The implementation objective for marine and estuarine fishes and large invertebrates is to maintain, improve, and restore populations of these species to levels that existed in the early 1980s. Meeting this objective would contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of water in the Bay-Delta.

General targets that will assist in meeting the implementation objective include:

- Increase abundance of marine/estuarine fish and large invertebrates, particularly in dry years.
- Reduce loss to water diversions.
- Improve distributions in dry and normal water years.

General programmatic actions that will contribute to achieving the targets for marine/estuarine fishes and large invertebrates include:

- Improve winter/spring Delta outflow.
- Restore tidal wetland habitat.
- Improve aquatic foodweb.
- Reduce losses of larvae and juvenile marine/estuarine fish at water diversions in the Bay and Delta, particularly during drier years.
- Limit further introductions of non-native species especially from ship ballast water.
- Reduce the input of toxic pollutants into Central Valley waterways.



INTRODUCTION

Bay-Delta aquatic foodweb organisms include bacteria, algae, zooplankton (e.g., copepods and cladocerans), epibenthic invertebrates (e.g., crayfish, Neomysis and Crangon shrimp), and benthic invertebrates (e.g., clams). Foodweb organisms are essential for the survival and productivity of fish, shorebird and other higher order animal populations in the Bay-Delta estuary. Some organisms are non-native species (e.g., certain zooplankton and Asian clams) that may be detrimental to native species and the foodweb in general. Recent declines in aquatic foodweb organisms of the Bay-Delta, particularly in drier years, has caused a reduction in overall Bay-Delta productivity. Important aquatic foodweb organisms include algae, bacteria, rotifers, copepods, cladocera, and mysid shrimp.

RESOURCE DESCRIPTIONS

The foodweb of the Bay-Delta ecosystem consists of all the plants, invertebrates, and other lower trophic-level organisms that serve as prey for fish, water birds, and other higher trophic-level resources of the ecosystem. Foodweb productivity of the Bay-Delta estuary is dependent primarily on the supply of nutrients and plant biomass production and transport (See Bay-Delta Aquatic Foodweb Process)..

Plant communities in the Bay-Delta aquatic foodweb consist mostly of benthic algae and phytoplankton produced in the estuary and its watershed, and vascular-plants in riparian and wetland communities adjacent to the system. Algae are generally small (diameter <0.1 millimeters [mm]), easily transported, and highly nutritious. Phytoplankton are related to algae but small enough to float in the water. Most vascular-plants, by contrast, are much larger.

The Bay-Delta foodweb has undergone a number of changes since the 1960s. Most notably, phytoplankton abundance has declined in important fish nursery areas of Suisun Bay and the western Delta (Lehman 1996). A pattern of very low phytoplankton levels in Suisun Bay and the Delta beginning in 1987 concerns many scientists. Low levels in Suisun Bay and the Delta since 1986 may be the result of high densities of Asian clams (*Potamocorbula amurensis*) that colonized the Bay after being accidentally introduced from the ballast waters of ships. Large numbers of the clams colonized this area of the estuary during the drought period from 1987 to 1992 (Kimmerer and Orsi 1996).

Aquatic invertebrate population trends followed those of phytoplankton over the past three decades. Species that once dominated the aquatic invertebrate community have become relatively scarce, while some others have increased in relative abundance. Many native species have become less abundant or more narrowly distributed, while dozens of new non-native species have become well established and widely dispersed. In general, the abundance of plankton has declined, while populations of many bottom-dwelling invertebrates, most notably Asian clams, have increased. This transition has been most evident in Suisun Bay and other traditionally important fish-rearing areas. Also in these areas, populations of rotifers, copepods, and other relatively small species have declined substantially since monitoring began in the 1960s (Kimmerer and Orsi 1996). This pattern is perhaps most dramatic for the mysid shrimp, which have declined to less than one-tenth of their former abundance, particularly since 1986 (Orsi and Mecum 1996). The continued decline from 1993 to 1995, despite the return of higher flows, is of particular concern. These declines in zooplankton abundance have roughly coincided with the decline in algae, one of the main food sources for the zooplankton.

The deterioration of the zooplankton community and its algal food supply in key habitat areas of the Bay-Delta is a serious problem because striped bass, delta smelt, chinook salmon, and other species that use Suisun Bay and the Delta as a nursery area feed almost exclusively on zooplankton during early stages of their life cycles. Research indicates that survival and growth of fish larvae generally increase with increased concentration of zooplankton. Declines in the production of juveniles of these fish species appear to coincide with the declines in algae and zooplankton. Modifying the Bay-Delta ecosystem in ways that will lead to increased algae and zooplankton abundance may be critical to restoring Bay-Delta fish populations and improving the health of its ecosystem.

Areas of the Bay-Delta where hydraulic conditions allow food resources to accumulate in the water column rather than settling or washing out are important habitats for plankton foodweb organisms. This accumulation of food resources results from passive processes and from active algal, microbial, and zooplankton reproduction. The comparatively benign hydraulic conditions and abundant food resources characterizing the western Delta and Suisun Bay permit the development of high zooplankton populations on which many estuarine resident and anadromous fish depend during their early life stages. Horizontal salinity stratification enhances this process, especially when the salinity front (sometimes referred to as X2) or the "entrapment zone" is in Suisun Bay (Arthur and Ball 1979).

The decline of plankton populations in the Bay-Delta may also be a result, at least in part, of the effects of heavy metals, herbicides, pesticides or other toxic substances. Low concentrations of these substances in the water column may act individually or in combination to reduce productivity of plant and animal plankton. Research to determine the effects of these toxicants on plankton is currently underway.

VISION

The vision for the Bay-Delta aquatic foodweb organisms is to restore the Bay-Delta estuary's once-productive food base of aquatic algae, organic matter, microbes, and zooplankton communities.

Restoring the Bay-Delta foodweb organisms would require enhancing plankton growth and reducing loss of plankton to water exports, particularly in drier years. Several options exist for enhancing plankton growth. Improving Delta inflow and outflow in spring of drier years will be an essential element of any plan. Other elements include reducing losses to exports from the system and reducing the amount of toxic substances entering the system.

Additional improvements can be gained by increasing shallow-water habitat and tidal wetlands in the Bay and Delta. Increasing the acreage of floodplain lakes, sloughs, and other backwaters in the Sacramento River drainage will increase organic matter inputs to the Delta. This increase in plankton food supply will help increase population growth.

Restoring tidal action to leveed lands in San Pablo Bay and Suisun Marsh will increase habitat for aquatic foodweb organisms. The Yolo and Sutter Bypasses offer potential opportunities to produce more permanent slough, riparian, and wetland habitats in the Sacramento River floodplain. Setback levees or improved riparian and shallow-water habitat along leveed reaches of the rivers and Delta offer additional opportunities to increase the abundance of foodweb organisms in the Bay and Delta.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore the abundance of Bay-Delta aquatic foodweb organisms would involve the cooperation and support from established programs underway to restore habitat and fish populations in the Bay-Delta including the following:

- The Recovery Plan for the Sacramento-San Joaquin Delta Native Fishes calls for improving flows, reducing diversions, and increasing habitat.
- The Salt Marsh Ecosystem Recovery Plan calls for improving wetland habitat in the Bay.
- The Central Valley Project Improvement Act (PL 102-575) and its associated Anadromous Fish Restoration Plan include provisions to reduce losses of organisms into water diversions, to restore aquatic habitat, to improve water quality, to improve freshwater flows, and to restore wetland and riparian habitats in the rivers and Bay-Delta.
- The Steelhead Trout, and Anadromous Fisheries Program Act of 1988 includes elements to improve freshwater flows and riparian habitats in the Sacramento and San Joaquin Rivers and their tributaries.
- The Delta Wildlife Habitat Protection and Restoration Plan include protection and improvements to riparian and wetland habitats of the Bay-Delta.
- Central Valley Habitat Joint Venture includes restoration of riparian and wetlands of the rivers, Delta, and Suisun Marsh.
- California Senate Concurrent Resolution 28 has set a goal of doubling wetland acreage by the year 2000.
- San Francisco Estuary Project planning for wetland protection and restoration, and water quality protection and improvement.
- San Joaquin River Management Plan is a plan to restore riparian and wetland habitat and improve water quality in the San Joaquin River and its tributaries.
- SWRCB and RWQCB efforts to restore wetlands and improve water quality of the rivers and Bay-Delta.
- Suisun Resource Conservation District is developing wetlands restoration and management plans.
- Riparian Habitat Joint Venture will restore riparian habitats.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Improving the abundance and distribution of important aquatic foodweb organisms of the Bay-Delta is integrally linked with wetland and riparian habitat restoration, water quality (contaminants) improvement, and Central Valley streamflow improvements.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for Bay-Delta aquatic foodweb organisms is to maintain, improve, or restore the population densities of phytoplankton, zooplankton, mysid shrimp and other invertebrates to sustainable levels, with special emphasis on native species.

General targets that will assist in meeting the implementation objective include:

- Increase abundance of important food web organisms to 1960s level of abundance
- Reduce influence of non-native species in foodweb communities
- Improve distribution of important foodweb organisms in Bay-Delta.

General programmatic actions that will contribute to achieving the targets include:

- increase late winter and spring Delta outflow
- reduce losses to water diversions
- opening leveed lands to tidal or seasonal floodflows;
- increasing the array of sloughs in the Delta;
- reduce influx of non-native species;
- protecting and restoring shallows, shoals, and channel islands in the Delta; and
- providing more natural floodplains and meander belts along rivers.

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PERENNIAL GRASSLAND SPECIAL-STATUS PLANT SPECIES

INTRODUCTION

Perennial grassland was historically common throughout the Central Valley. Most perennial grassland has been lost or converted into annual grassland dominated by non-native species. Perennial grassland provides important breeding and foraging habitat for many wildlife species and supports several special-status plant species, including fragrant fritillary (*Fritillaria liliacea*) and recurved larkspur (*Delphinium recurvatum*).

SPECIES DESCRIPTIONS

Fragrant fritillary (*Fritillaria liliacea*) is a slender, bulb-forming herbaceous perennial of the Lily family (Lileaceae). Its flowers are white and typically have a green or yellow throat. Fragrant fritillary is considered a species of concern by the USFWS and is considered rare, threatened, or endangered by the California Native Plant Society (List 1B). Fragrant fritillary occurs primarily in the outer Coast Ranges from Sonoma County to Monterey County, with disjunct occurrences in Solano County. Many populations occur on public lands, and several occurrences are found on The Nature Conservancy's Jepson Prairie Preserve. The habitat of the species is low elevation grasslands or coastal scrub with clay soils, typically characterized by serpentine. The primary threats to this species include livestock grazing, agriculture, recreational activities, and urban development (NDDB 1996).

Recurved larkspur (*Delphinium recurvatum*) is a perennial herb with light blue and white flowers in the Buttercup family (Ranunculaceae). It is considered a species of concern by the USFWS and is considered rare, threatened, or endangered by the California Native Plant Society (List 1B). Recurved larkspur inhabits poorly drained, fine, alkaline soils in grassland in the Central Valley and surrounding foothills of the Coast Ranges from Colusa County to Kern County (NDDB 1996). Much of the larkspur's habitat has been converted to agriculture, and is also threatened by grazing.

VISION

The vision for fragrant fritillary, recurved larkspur, and perennial grassland species is to protect existing populations, promote the recovery of the species' habitat, establish new populations, and manage occupied sites properly to ensure the long-term viability of the species. A site-based evaluation of existing populations would be conducted, criteria on habitat and populations conditions developed, and all sites ranked based on the criteria in terms of low to high quality habitat. Based on the site rankings, the highest quality populations would be protected.

To ensure the long-term viability of the species, lower quality sites would be evaluated for potential habitat restoration or enhancement opportunities. Existing populations would be expanded through habitat restoration, enhancement, and appropriate management. The species' grassland habitat would be protected from overgrazing and trampling by livestock. Appropriate management techniques, such as lowered grazing regime, prescribed burns, and exotics control would be evaluated and appropriate techniques implemented to promote

The health and vigor of existing and restored populations.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for perennial grassland special-status plant species is to preserve and restore perennial grassland habitat in conjunction with restoration of wetland and riparian habitats. The targets for these species include identifying and protecting high-quality habitats and populations and ensuring the long-term viability of the species on higher ranked sites.

- Acquire lands supporting existing populations or develop cooperative relationships with landowners to protect existing populations, beginning with the highest quality sites.
- Develop appropriate methods to protect and restore habitat and populations of special-status plant species.
- Manage protected areas occupied by the species to promote conditions favorable for the establishment, growth, and vigor of the species.
- Conduct a site-based evaluation of populations and rank sites based on criteria developed to assess habitat and populations conditions.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Restoring perennial grassland is an objective of the Cache Creek Corridor Restoration Plan and Yolo County Habitat Conservation Plan. Additional efforts to restore habitat for fragrant fritillary and recurved larkspur will involve cooperation with programs managed by several agencies and organizations. These include:

- Cosumnes River Preserve,
- Grizzly Slough Wildlife Area,
- Jepson Prairie Preserve,
- Putah Creek South Fork Preserve,
- Stone Lakes National Wildlife Refuge, and
- Woodbridge Ecological Reserve.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Fragrant fritillary and recurved larkspur are linked with a habitat ecosystem element, perennial grassland. Land use, human disturbance, and non-native species are stressors that could adversely affect the perennial grassland special-status plants.

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Natural Diversity Data Base. 1996. Record search for occurrence of *Fritillaria liliaceae* and *Delphinium recurvatum*. California Department of Fish and Game, Sacramento, CA.

TIDAL BRACKISH AND FRESHWATER MARSH SPECIAL-STATUS PLANT SPECIES

INTRODUCTION

Tidal brackish and freshwater marshes occur in transitional areas between open-water and upland habitats throughout the Bay and Delta and are important habitats for many plant, fish and wildlife of the Bay-Delta. Substantial loss of tidal brackish and freshwater marshes has been incurred as a result of reclamation and channel dredging and scouring, leading to the decline of many native fish, wildlife, and plant species. Special-status plants inhabiting Bay-Delta tidal marshes include Mason's lilaeopsis (*Lilaeopsis masonii*), Suisun Marsh aster (*Aster lentus*), bristly sedge (*Carex comosa*), Suisun thistle (*Cirsium hydrophyllum* var. *hydrophyllum*), soft bird's-beak (*Cordylanthus mollis* ssp. *mollis*), rose-mallow (*Hibiscus lasiocarpus*), Delta tule pea (*Lathyrus jepsonii* var. *jepsonii*), and Delta mudwort (*Limosella subulata*).

SPECIES DESCRIPTIONS

Mason's lilaeopsis. Mason's lilaeopsis is a minute, turf-forming perennial plant in the carrot family (Apiaceae). It spreads by rhizomes and produces long, narrow, jointed leaves. Mason's lilaeopsis is state-listed as rare and is considered rare, threatened, or endangered by the California Native Plant Society (List 1B). Mason's lilaeopsis is semiaquatic and is usually found on saturated clay soils which are regularly inundated by waves and tidal action. Its known distribution extends from the margins of the Napa River in Napa County, east to the channels and sloughs of the Sacramento-San Joaquin Delta in Contra Costa, Solano, Sacramento, Yolo, and San Joaquin Counties. Approximately 50 occurrences of Mason's lilaeopsis were known in 1991 (DFG 1991). Populations of this species are small and fractured and few large contiguous sites exist on non-leveed sloughs or on eroding in-channel islands.

Mason's lilaeopsis has lost a large amount of its habitat through direct loss from flood control structures and rip-rap and through erosion of remnant in-channel islands. Widening of Delta channels for water transport, dredging and dumping of spoils, recreational development, and changes in water quality resulting from decreased flows in the Delta also threaten Mason's lilaeopsis. Although much of the habitat for Mason's lilaeopsis is privately owned, several State and Federal agencies have jurisdiction over the Delta waterways. One site is protected in Solano County on a DFG Ecological Reserve. DFG has been active in coordinating research on and trying to transplant the species. The trend for Mason's lilaeopsis is one of decline (DFG 1991).

Suisun Marsh aster. Suisun Marsh aster is a rhizomatous perennial herb in the sunflower family (Asteraceae). Suisun Marsh aster is on CNPS's List 1B. Suisun Marsh aster has habitat requirements and a distribution similar to that of Mason's lilaeopsis, but is not known from Alameda County. Suisun Marsh aster is threatened by marsh habitat alteration and loss. Factors leading to marsh habitat alteration and loss include development, agriculture, recreation, channelization, channel maintenance activities, and marsh drainage.

Bristly sedge. Bristly sedge is a rhizomatous perennial herb in the sedge family (Cyperaceae). Bristly sedge is considered rare, threatened, or endangered in California but more common elsewhere by CNPS (List 2). Bristly sedge occurs around lake margins in Contra Costa, Lake, Shasta, San Joaquin, and Sonoma Counties. It is also widespread outside of California, occurring in Idaho, Oregon, and Washington. Bristly sedge is threatened by marsh habitat alteration and loss.

Mad-dog skullcap. Mad-dog skullcap is a rhizomatous perennial herb mint family (Lamiaceae). Mad-dog skullcap is considered rare, threatened, or endangered in California but more common elsewhere by CNPS (List 2). Mad-dog skullcap inhabits mesic meadows and marshes and in California is known from only 2 occurrences in Inyo and San Joaquin Counties (Skinner and Pavlik 1994). Mad-dog skullcap also occurs in New Mexico and Oregon. Mad-dog skullcap is threatened by marsh habitat alteration and loss.

Suisun thistle. Suisun thistle is a perennial herb in the sunflower family (Asteraceae). It has slender, erect stems that are 3-4.5 feet tall and are well-branched above. The spiny leaves are deeply lobed. The flower heads are pale lavender-rose and the flower head bracts have a distinct green, glutinous ridge on the back. Suisun thistle is proposed for federal listing as endangered and is on CNPS's List 1B. Suisun thistle is known from only 2 locations in the Suisun Marsh in Solano County (CFR 60(112)). It occurs on the edges of salt and brackish marshes that are periodically inundated during high tides. The total number of individuals of Suisun thistle is a few thousand individuals (CFR 60(112)). One occurrence is on DFG lands and a second occurrence is on Solano County Farmland and Open Space Foundation lands.

Suisun thistle was probably more widespread in the past, but reductions in salt marsh habitat that have resulted from drainage or filling, and possibly water pollution, may have contributed to the species' decline (Niehaus 1977). Its present highly restricted distribution increases its susceptibility to catastrophic events such as disease or pest outbreak, severe drought, oil spills, or other natural or human caused disasters. Continued habitat conversion, habitat fragmentation, indirect effects from urban development, increased salinity, projects that alter natural tidal regime, mosquito abatement activites, competition with non-native plants, and inadequate regulatory mechanisms also threaten this taxon (CFR 60(112)).

Soft bird's-beak. Soft bird's-beak is a sparingly-branched, semi-parasitic herbaceous annual plant in the figwort family (Scrophulariaceae). Its stems are covered by soft hairs, and it bears white two-lipped flowers. Soft bird's-beak is proposed for federal listing as endangered and is state-listed as rare. Soft bird's-beak occurs along the northern shores of the San Francisco Bay, in Suisun Marsh, and in the salt marshes south of Suisun Bay. A dozen historical occurrences were known from Marin to Contra Costa Counties, where the counties border San Francisco Bay. In 1991, the species was known to be extant at only three sites: Benicia State Recreation Area, DFG land along the Napa River at Fagan Slough, and Point Pinole Regional Shoreline (California Department of Fish and Game 1992). Recently, several new populations have been discovered at salt marshes near Martinez and at Suisun Marsh (Natural Diversity Data Base 1996). Soft bird's-beak inhabits the upper reaches of salt grass-pickleweed marshes at or near the limits of tidal action. Soft bird's-beak is susceptible to factors similar to those listed above for Suisun thistle (CFR 60(112)).

Rose-mallow. Rose-mallow is a herebaceous perennial plant in the Mallow family (Malvaceae). Rose-mallow is considered rare, threatened, or endangered in California but more common elsewhere by CNPS (List 2). Rose-mallow is relatively widespread along the lower portions of the Sacramento and San Joaquin Rivers, but most occurrences are very small. the species prefers open, freshwater marsh habitats along slow-moving watercourses, and is often found on peaty substrates in association with bulrush (*Scirpus* sp.). Rose-mallow does not tolerate shade from dense woody vegetation. Rose mallow is threatened by marsh habitat alteration and loss. Factors leading to marsh habitat alteration and loss include development, agriculture, recreation, channelization, channel maintenance activities, and marsh drainage.

Delta tule pea. Delta tule pea is a herebaceous perennial plant in the legume family (Fabaceae). Delta tule pea is on CNPS's List 1B. Delta tule pea inhabits freshwater and brackish marshes in Alameda, Contra Costa, Fresno, Marin, Napa, Sacramento, San Benito, Santa Clara, San Joaquin, and Solano Counties. Delta tule pea is threatened by marsh habitat alteration and loss. Factors leading to marsh habitat alteration and loss include development, agriculture, recreation, channelization, channel maintenance activities, and marsh drainage.

Delta mudwort. Delta mudwort is a stoloniferous perennial herb in the figwort family (Scrophulariacae). Delta mudwort is considered rare, threatened, or endangered in California but more common elsewhere by CNPS (List 2). Delta mudwort inhabits marshes in Contra Costa, Sacramento, San Joaquin, and Solano Counties. It is also found on the Atlantic Coast. Delta mudwort is threatened by marsh habitat alteration and loss. Factors leading to marsh habitat alteration and loss are similar to those described above for Delta tule pea.

VISION

The vision for the tidal brackish and freshwater marsh guild of plant species is to provide protection for existing populations and restore habitat to provide sites for expansion of the species. Existing populations should be protected through acquisition or cooperative efforts with landowners, beginning with the highest quality sites. A site-based evaluation of populations would be conducted to all rank sites based on criteria developed to assess habitat and population conditions. Higher ranked sites that are protected would serve as a source of propagules for restored areas.

Higher quality sites will also be evaluated for potential enhancement opportunities through habitat expansion. Moderate or low quality sites will be restored to low elevation intertidal habitats and establishment of species in this guild promoted. Restoration efforts would include protecting eroding sites, such as on in-channel islands, from further erosion. During the restoration of habitat, ecological functions such as sediment deposition and erosion to balance the formation and loss of intertidal habitats would be promoted.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the tidal brackish and freshwater marsh special-status plant species is to protect existing populations and restore habitat to promote the establishment of additional populations. The general target for the tidal brackish and freshwater marsh special-status plant species is to establish and protect a large enough number of populations of each species to maintain genetic diversity, prevent species extinction from localized catastrophic occurrences, and promote the sustainability of each species.

The following actions would contribute to improving the tidal brackish and freshwater marsh special-status plant species populations:

- Conduct a site-based evaluation of populations and rank sites based on criteria developed to assess habitat and populations conditions.
- Acquire lands supporting existing populations or develop cooperative relationships with landowners to protect existing populations, beginning with the highest quality sites.
- Develop appropriate methods to protect and restore habitat and populations of the tidal

brackish and freshwater marsh special-status plant species.

- Manage protected areas occupied by the species to promote conditions favorable for the establishment, growth, and vigor of the species. Include management techniques such as exotic weed control and hydrologic regulation.

- Restore moderate or low quality sites to low elevation intertidal habitats and promote establishment of species in this guild. During the restoration of habitat, promote ecological functions such as sediment deposition and erosion to balance the formation and loss of intertidal habitats.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore habitat for the Delta plant species will involve cooperation with programs being implemented by DFG to promote their occurrences and cooperation from agencies with responsibility or authority for maintaining or restoring tidal perennial habitat, including:

- California Department of Fish and Game,
- U.S. Fish and Wildlife Service,
- U.S. Army Corps of Engineers,
- Delta Protection Commission
- Benecia State Recreation Area,
- Point Pinole Regional Shoreline, and
- Solano County Farmland and Open Space Foundation.

Other programs that could be solicited for collaboration to benefit the Delta species include the Montezuma Wetlands Project and Tidal Wetlands Species Recovery Plan

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

The Delta guild of plant species is integrally linked with the restoration of tidal perennial aquatic habitat. Stressors that could affect the Delta guild include non-native species such as water hyacinth that shades out habitat when occurring in dense patches; levees, bridges, and bank protection; dredging' water management; human disturbance; and contaminants. Tides are an important primary physical process that affects the tidal brackish and freshwater plant species guild.

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AQUATIC HABITAT SPECIAL-STATUS PLANT SPECIES

INTRODUCTION

Aquatic habitats associated with shorelines of rivers and the Delta include shaded riverine aquatic and riparian habitats. Riverine aquatic habitat shaded by riparian vegetation provides important habitat for many species of fish, waterfowl, and wildlife. Nontidal perennial aquatic habitat is another aquatic habitat that occurs in the Bay-Delta as permanent open water that is no longer subject to tidal influences.

Riverine aquatic habitat is characterized by the relatively shallow submerged and seasonally flooded areas in estuary and river channel beds. Channel beds contain gravel beds, bars, and riffles; transient sandy shoals; waterlogged woody debris piles; and the shaded riverine aquatic habitat zone. This habitat zone is located where the river meets the riparian canopy. Riverine aquatic zones provide spawning substrate, rearing and escape cover, feeding sites, and refuge from turbulent stormflows for fish and other aquatic organisms. Riparian and riverine aquatic habitats are created and sustained by natural fluvial processes associated with rivers.

The nontidal perennial aquatic habitat is present in certain low-elevation areas in the Bay-Delta estuary. In many places within the Delta, this habitat type has replaced the native tidal aquatic habitats that existed prior to reclamation. Most nontidal perennial aquatic habitat areas were established by constructing dikes and levees as part of reclamation activities. As land was converted to agricultural uses, perennial aquatic habitats established in large agricultural drains; small farm ponds; industrial ponds; ponds managed for waterfowl and other wildlife; and Delta island blowout ponds, which were created by levee failures that scoured island interiors deeply enough to maintain permanent water through seepage. Some historical nontidal perennial habitat was created naturally as a result of shifts in river alignments that occasionally resulted in establishment of isolated oxbow lakes. Eel-grass pondweed *(Potamogeton zosteriformis)* is the only aquatic habitat special-status plant species that is expected to occur in the study area.

SPECIES DESCRIPTION

Eel-grass pondweed *(Potamogeton zosteriformis)* is an annual aquatic plant with narrow linear leaves that grows less than 24 inches tall and is submerged in ditches, ponds, lakes, and slow-moving streams generally below the 5,000-foot elevation (Mason 1957, Hickman 1993). Eel-grass pondweed is more common outside the State of California, although suitable habitat exists for it in the Central Valley, where it is considered rare. It is known to have occurred in Lassen, Shasta, and Modoc Counties in the State based on six records in the California Department of Fish and Game Natural Diversity Data Base (1996) that were documented between 1897 and 1949. Eel-grass pondweed is expected to occur in the San Joaquin River Delta (Mason 1957, Munz and Keck 1973). The species has not been listed for protection by the State or the federal government. It has been assigned to List 2 by the California Native Plant Society (Skinner and Pavlik 1994).

VISION

The vision for aquatic habitat plant species is to provide protection for and enhance existing populations. The vision for eel-grass pondweed and other aquatic habitat plant species should be initiated by conducting surveys in the project area to identify locations of sites. Following identification of sites, it will be necessary to conduct site-based evaluations of populations, develop criteria on habitat and population conditions, and rank all sites based on the criteria in terms of low- to high-quality. Higher ranked sites should be identified for protection. Restoration efforts should be focused on restoring existing habitat and promoting establishment of aquatic plant species on restored sites or at other sites with suitable habitats.

Existing populations of aquatic species should be protected through acquisition or cooperative efforts with landowners, beginning with the highest quality sites.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for eel-grass pondweed is to ensure the recovery of this special-status species in order to contribute to overall species diversity in aquatic habitats. The targets for eel-grass pondweed include identifying and protecting high-quality habitats and populations throughout the range of this species in the study area, and ensuring the long-term viability of the species on higher ranked sites. Implementation of the following actions would contribute to achieving the targets:

- Conduct a site-based evaluation of populations, develop criteria on habitat and population conditions, and rank all sites based on the criteria in terms of low- to high-quality. Based on the ranking of sites identify the higher ranked sites for protection.
- Protect higher ranked sites through acquisition or cooperative efforts with landowners.
- Conduct studies to determine the microhabitat requirements of eel-grass pondweed and determine reasons for limited distribution.
- Develop and implement a habitat management plan to protect eel-grass pondweed on higher ranked sites.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to achieve the vision for riverine aquatic habitat (including riparian habitat) may involve coordination with other programs. These include:

- U.S. Army Corps of Engineers proposed reevaluation of the Sacramento River flood control project and ongoing bank protection project, including more comprehensive floodplain management and river ecosystem restoration opportunities;
- SB1086 Advisory Council efforts and river corridor management plan for the Sacramento River;
- the San Joaquin River Parkway and Management plans;
- ongoing Sacramento Valley conservation planning by the Nature Conservancy and other private nonprofit conservation organizations;
- expansion plans and conservation easements underway for the Sacramento River National Wildlife Refuge and California Department of Fish and Game Sacramento River Wildlife Management Area; and
- ongoing coordination efforts and programs of the Wildlife Conservation Board, including the Riparian Habitat Joint Venture.

Linkage with Other Ecosystem Elements

Riverine aquatic habitat is important to many fish, wildlife, and plant species and communities. It is adversely affected by stressors that include levee construction, gravel mining, flow patterns, fragmentation of existing stands of riparian vegetation, competition and displacement by non-native plant species.

Restoration of nontidal perennial aquatic habitat is linked with ecosystem processes including:

- the geologic and hydrologic condition, stream meander, and tidal function necessary to maintain permanent surface water;
- a range of elevations sufficient to support deep-water (greater than 3 feet in depth) and shallow-water areas; and
- adjacent wetland and riparian (streambank) vegetation.

The value of nontidal perennial aquatic habitat to wildlife greatly increases if emergent vegetation is present along shorelines and in shallow-water areas. Adjacent dense upland herbaceous vegetation and riparian woodland further increase the value to wildlife.

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VERNAL POOL SPECIAL-STATUS PLANT SPECIES

INTRODUCTION

Vernal pools are seasonally flooded depressions that support a distinctive biota adapted to periodic or continuous inundation during the wet season and desiccated soils during the dry season (Holland and Jain 1977, Holland 1978, Thorne 1984, Jones & Stokes Associates 1990). Vernal pools usually occur in troughs between the ridges of a gently rolling or reticulated landscape, in the depressions between small mounds in a landscape dotted by "mima mounds", or on localized flats or steps in a seasonally wet swale. Some appear as isolated anomalies on ridge tops or flat terrain. Vernal pools vary in size from several yards to well over 1 acre, but most range from several thousandths to a few tenths of an acre. The largest vernal pools are really seasonal lakes, like Olcott Lake at the Jepson Prairie Preserve in Solano County and Boggs Lake at the Boggs Lake Preserve in Lake County.

Vernal pools support a unique associated of plant species. Some of the plants are restricted to vernal pools, while others occur primarily in vernal pools but also occur in other seasonal wetland habitats. Vernal pools are well known for their high level of endemism (Jain 1976) and abundance of rare, threatened, or endangered species (Skinner and Pavlik 1994, Jones & Stokes Associates 1990).

SPECIES DESCRIPTION

Colusa grass *(Neostapfia colusana)* is a pale green annual member of the grass family (Poaceae), with several stems of loosely folded, clasping leaves and thick terminal spikes of flowers. Colusa grass is state listed as endangered and federally listed as threatened. It is considered rare, threatened, or endangered in California and elsewhere by the California Native Plant Society (CNPS) List 1B. Colusa grass grows in the bottoms of large or deep vernal pools with substrates of adobe mud and is somewhat resistant to light grazing. Colusa grass is endemic to the southern Sacramento and northern San Joaquin Valleys. Its historical distribution included Merced, Stanislaus, Solano and Colusa Counties, but is now extirpated from Colusa County. Two new populations have been found in Yolo County. The primary reasons for decline of Colusa grass include the conversion of vernal pools to agricultural and developed lands, heavy grazing by cattle, and competition from introduced weedy species that tend to displace it. (DFG 1992)

Boggs Lake hedge-hyssop *(Gratiola heterosepala)* is a small, semi-aquatic, herbaceous annual in the figwort family (Scrophulariaceae). It has opposite leaves, blunt, unequal sepals, and yellow and white flowers on short stalks. Boggs Lake hedge-hyssop is state endangered and considered rare, threatened, or endangered in California and elsewhere by CNPS (List 1B). Boggs Lake hedge hyssop is found in Fresno, Lassen, Lake Madera, Modoc, Placer, and Sacramento, Shasta, San Joaquin, Solano, and Tehama Counties and in Oregon. This species is found in shallow waters or moist clay soils of vernal pools and lake margins. Boggs Lake hedge hyssop has undergone substantial habitat reduction from development and agricultural conversion. Current threats include agriculture, development, grazing, and ORV's. Many occurrences are on privately owned land. (DFG 1992)

Contra Costa goldfields *(Lasthenia conjugens)* is a showy spring annual in the aster family (Asteraceae) that grows 10 to 30 centimeters tall with opposite light green leaves. Contra Costa goldfields is federally listed as endangered and is on CNPS list 1B. The historical distribution of Contra Costa goldfields extended from Mendocino to Santa Barbara Counties. Currently its distribution is limited to a few locations in

Solano and Napa Counties. It inhabits vernal pools and seasonally moist grassy areas. In the past, the species may have also occurred in coastal prairies (Ornduff 1979). The decline of the Contra Costa goldfields has been attributed to the loss of vernal pools by development and agriculture. Continued threats include urbanization and overgrazing.

Legenere *(Legenere limosa)* is a slender annual that grows in wet margins of deep vernal pools. Legenere is considered by the U.S. Fish and Wildlife Service (USFWS) to be a species of concern and CNPS list 1B. Historical distribution of Legenere includes Lake, Napa, Placer, Sacramento, San Mateo, Solano, Sonoma, Stanislaus and Tehama Counties. It has now become extirpated from Sonoma and Stanislaus Counties. At the Jepson Prairie Preserve it is found in the bottom of hogwallow. Threats to this species are primarily loss of vernal pools by agriculture. Other threats include grazing and development.

Alkali milk-vetch *(Astragalus tener var. tener)* is rare, threatened, or endangered in California and elsewhere by CNPS (List 1B). Historical distribution of Alkali milk-vetch includes Alameda, contra Costa, Merced, Monterey, Napa, San Benito, San Francisco, San Joaquin, Solano, Sonoma, Stanislaus, and Yolo Counties. Currently its distribution is Merced, Napa, Solano, and Yolo Counties. The primary threat to this species is sheep and cattle grazing (NDDB 1996).

Dwarf downingia *(Downingia pusilla)* is considered rare, threatened, or endangered in California and elsewhere by CNPS (List 1B). Dwarf downingia occurs in margins of vernal pools, swales. Distribution includes Merced, Mariposa, Napa, Placer, Sacramento, Solano, Sonoma, Stanislaus and Tehama Counties. Threats to this species are ORV's, grazing and development (NDDB 1996).

Crampton's tuctoria *(Tuctoria mucronata)* is a sticky, aromatic annual grass, with a dense spike of overlapping flower spikelets that emerge from the upper leaves. Crampton's tuctoria is state and federally listed as endangered and CNPS list 1B. It occurs in only two counties Solano and Yolo. It grows in the clay bottoms of drying vernal pools and lakes. The Nature Conservancy owns and protects a portion of the habitat at the Jepson Prairie Preserve, but the plant has not been seen since 1987 at the preserve (DFG 1992). Threats to the two known occurrences include alternation of local drainage patterns that feed the pools, off-road vehicle recreation, local farming operations, and trampling by livestock. Roads and transmission corridors have also degraded the habitat. Most of Crampton's tuctoria habitat is privately owned. The USFWS has prepared a recovery plan for Crampton's tuctoria which provides management recommendations (DFG 1992).

Heartscale *(Atriplex cordulata)* is considered by the USFWS to be a species of concern and CNPS list 1B. Distribution of heartscale includes Alameda, Contra Costa, Butte, Fresno, Glenn, King, Kern, Madera, Merced, Solano, and Tulare Counties and no longer occurs in San Joaquin, Stanislaus or Yolo Counties (NDDB 1996).

VISION

The vision for vernal pool plant species is to provide protection for and enhance existing populations. Existing populations should be protected through acquisition or cooperative efforts with landowners, beginning with the highest quality sites. Preservation and proper management of all existing populations would ensure the long-term viability of the species. To provide for proper management on protected sites, research would be conducted to determine the optimal conditions for the growth. For example, on sites with a high cover of non-native species, experimental burning and/or grazing would be conducted to determine if such treatments are beneficial for the species. Colusa grass's response to light and moderate grazing could also be investigated. Research on reproduction and recruitment would be conducted to better understand the species' biology.

Following experimental research, habitat management techniques to promote conditions suitable for the growth and establishment would be implemented. This may include, but is not limited to, reduction in grazing; use of prescribed burns' restoration of winter flood/summer drought regime; and removal of other stresses.

Implementation Objective, Targets, and Programmatic Actions

The implementation objective for the vernal pool special-status plant species is to protect existing populations and to acquire and restore habitat for long-term viability of the species. The targets for vernal pool special-status species include identifying high-quality habitats and populations and restoration and reestablishment of populations in order to maintain diversity and ensure the sustainability of each species.

- Protect existing habitat and restore and reestablish vernal pool habitats within and adjacent to existing ecological reserves.
- Implement restoration of habitat and reintroduction of species on historic sites in conjunction with long-term monitoring and maintenance of existing and newly established populations.
- Conduct reproduction and recruitment research to better understand the species biology.
- Conduct site-based evaluation of populations and develop criteria for ranking sites and protection of high-quality sites.

Integration with Other Restoration Programs

Efforts to restore seasonal wetlands would involve cooperation with other restoration programs, including:

- Upper Sacramento River Fisheries and Riparian Habitat Council,
- California Department of Fish and Game wildlife areas,
- Jepson Prairie Preserve,
- Ducks Unlimited Valley Care Program,
- California Waterfowl Association,
- the Nature Conservancy,
- U. S. Fish and Wildlife Service,
- Yolo County Habitat Conservation Plan,
- and Central Valley Habitat Joint Venture.

Two occurrences of Colusa grass are currently protected: the Solano County occurrence at the Nature Conservancy's (TNC) Jepson Prairie Preserve and the Flying M Ranch in Merced County, where conservation easements protect some of the large vernal pools. Heartscale occurs with two other species dwarf downingia and legenere at the Nature Conservancy's Jepson Prairie Preserve.

Linkage with Other Ecosystem Elements

The vernal pool guild of plant species is linked with the restoration of vernal pool habitat.

Stressors that could effect these species include: non-native weedy grasses and grazing.

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INLAND DUNE SPECIAL-STATUS PLANT SPECIES

INTRODUCTION

Inland dunes are extremely limited to the Delta, occurring only in the vicinity of the Antioch Dunes Ecological Reserve. This habitat supports two plant and one butterfly species listed as endangered under the federal Endangered Species Act. Visions are provided here for the two plant species, Antioch Dunes evening-primrose (*Oenothera deltoides* ssp. *howellii*) and Contra Costa wallflower (*Erysimum captitatum* var. *angustatum*).

SPECIES DESCRIPTIONS

Antioch Dunes evening-primrose. Antioch Dunes evening-primrose is a showy, white-flowered, highly branched perennial herb with grayish toothed or divided leaves. It is a member of the evening primrose family (Onagraceae). Antioch Dunes evening-primrose is both state and federally listed as endangered. Additionally, this species is considered rare, threatened, or endangered in California and elsewhere by the California Native Plant Society (CNPS) (List 1B). Antioch Dunes evening-primrose is endemic to loose sand and stabilized dunes near river margins in the vicinity of Antioch. It is known from only 7 occurrences (Skinner and Pavlik 1994). Most remaining plants occur at the Antioch Dunes National Wildlife Refuge. In 1992, the population size of this species at 2 disjunct sites on the Antioch Dunes was only 1,200 plants (Greene 1994). Attempts have been made to introduce the species to several other locations with remnant dunes, including Brannan Island State Recreation Area in Rio Vista. Antioch dunes evening-primrose evolved from desert flora which occupied the sand dunes of the Sacramento Valley 5,000 to 8,000 years ago (Green 1994). In recent times, dune habitat in the Delta has been lost to conversion to agriculture, sand mining, and industrial development. Present threats include competition for water with ripgut brome (*Bromus diandrus*) and recreational and fire control activities. The recent trend for Antioch Dunes evening-primrose is one of stability, but its total population size and distribution is still very limited (DFG 1991).

Contra Costa wallflower. Contra Costa wallflower, a member of the mustard family (Brassicaceae), is a coarse-stemmed, erect, herbaceous biennial herb with yellowish-orange flowers. Contra Costa wallflower is state and federally listed as endangered and is also on CNPS's List 1B. Contra Costa wallflower co-occurs with Antioch Dunes evening-primrose at the Antioch Dunes NWR, and is known from only 2 occurrences at the Antioch Dunes. It is threatened by factors similar to those affecting Antioch Dunes evening primrose. The wallflower population is surveyed annually and has shown considerable increase since 1978 (DFG 1991).

VISION

The vision for Antioch Dunes evening-primrose and Contra Costa wallflower is to protect existing populations and ensure the long-term viability of the species through habitat restoration, enhancement, and appropriate management. Effective management techniques would be developed and employed to protect existing populations. Existing knowledge acquired primarily at the Antioch Dunes Refuge would serve as a basis of establishing effective management techniques. Prescribed burning is an example of a management technique that has been successful in promoting Antioch Dunes evening-primrose colonization. Controlling non-native competitors would also be an element of on-going management for the species. One study showed that removal of ripgut brome near adult Antioch Dunes evening-primrose plants increased seedling germination (Greene 1994).

Establishing additional populations would greatly increase the recovery potential for Antioch Dunes evening-primrose and Contra Costa wallflower. To promote the expansion of the species, historic inland dunes adjacent to existing ecological reserves in the Sacramento-San Joaquin Delta Ecological Zone would be reestablished and species establishment promoted. Sand dune creation techniques developed at the Antioch Dunes would be employed. Protecting and restoring inland dune scrub that serves as habitat for Antioch Dunes evening-primrose and Contra Costa wallflower would be enhanced by identifying areas that are not currently managed for their resource values. Appropriate methods to protect and restore identified areas would be developed. Protected habitat areas would be evaluated to determine effective restoration management practices to increase habitat value. The results of these evaluations would determine how habitat for Antioch Dunes evening-primrose and Contra Costa wallflower would be protected and restored.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the inland dune special-status plant species is to protect existing populations and restore habitat to promote the establishment of additional populations. The general target for the inland dune special-status plant species is to establish and protect a large enough number of populations of each species to maintain genetic diversity, prevent species extinction from localized catastrophic occurrences, and promote the sustainability of each species.

The following actions would contribute to improving the inland dune special-status plant species populations:

- Develop appropriate methods to protect and restore habitat and populations of the inland dune special-status plant species.
- Manage protected areas occupied by the inland dune special-status species to reduce disturbance of dunes and dune vegetation.
- Manage protected areas occupied by the species to promote conditions favorable for the establishment, growth, and vigor of the species. Include management techniques such as prescribed burning and exotic weed control.
- Acquire historic inland dunes adjacent to existing ecological reserves and reestablish dune habitat and inland dune special-status species populations.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore habitat for Antioch Dunes evening-primrose and Contra Costa wallflower will involve cooperation with programs managed by the Antioch Dunes National Wildlife Refuge. Cooperation from agencies with responsibility or authority for restoring inland dune habitat will be solicited. These include:

- California Department of Fish and Game,
- U.S. Fish and Wildlife Service,
- U.S. Army Corps of Engineers, and
- the Delta Protection Commission.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Antioch Dunes evening-primrose and Contra Costa wallflower are linked with a habitat ecosystem element, inland dune scrub. These species and habitat elements are closely associated with each other and are limited to the area near the Antioch Dunes Ecological Reserve. Non-native plant species are stressors that compete with Antioch Dunes evening-primrose and Contra Costa wallflower for habitat.

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AQUATIC HABITAT PLANT COMMUNITY GROUP

INTRODUCTION

Aquatic plant habitat in the Bay-Delta area is present in permanently flooded and intermittently exposed shallow water areas. These shallow water areas present important wetland habitat for dependent plant, wildlife, and fish species. The substantial loss of historic shallow water aquatic plant habitat has primarily resulted from reclamation and channel dredging and scouring. Loss of such habitat has reduced primary (plant) and secondary (invertebrate) productivity in the Bay-Delta area, changing important characteristics of the natural foodweb of the system and therefore leading to the decline of many native plant, fish, and wildlife species.

RESOURCE DESCRIPTION

Pondweeds with floating and submerged leaves. Aquatic plant habitat in the Bay-Delta area is dominated by pondweeds (*Polygonum* spp.) with floating or submerged leaves. Pondweeds are the sole or dominant herb in this community. Pondweeds with submerged leaves include crispate pondweed (*P. crispus*), eel-grass pondweed (*P. zosteriformis*), fennelleaf pondweed (*P. pectinatus*), leafy pondweed (*P. foliosus*), Nevada pondweed (*P. latifolius*), Richardson pondweed (*P. richardsonii*), Robbin pondweed (*P. robbinsii*), slenderleaf pondweed (*P. filiformis*), small pondweed (*P. pusillus*), and whitestem pondweed (*P. praelongus*). Pondweeds with floating leaves include alpine pondweed (*P. alpinus*), broadleaf pondweed (*P. amplifolius*), diverseleaf pondweed (*P. diversifolius*), floatingleaf pondweed (*P. natans*), grassleaf pondweed (*P. gramineus*), longleaf pondweed (*P. nodosus*), Nuttall pondweed (*P. epihydrus*), and shinning pondweed (*P. illinoensis*). The vegetative cover in the aquatic plant habitat ranges from continuous to intermittent or open.

VISION

The vision for the aquatic habitat plant community group is to protect and restore large areas of perennial shallow water that provide habitat for pondweeds and other associated plant and wildlife species. Areas protected and restored as aquatic plant habitat would be closely associated with areas protected and restored as tidal brackish and freshwater marsh plant habitat and tidal riparian plant habitat to promote habitat diversity.

Initial efforts should focus on protecting existing aquatic habitat plant community areas. Restored areas should be linked with existing healthy habitats where feasible to provide a source of vegetative propagules and to create large contiguous areas of aquatic plant habitat. Establishing the proper gradients relative to water levels will be key in promoting the establishment of the aquatic habitat plant community. Restored habitats should have natural gradients of open water, shallow water that is suitable for supporting pondweeds, marsh, riparian, and upland habitats to increase the habitat value for a greater diversity of species.

Many leveed lands in the Bay and Delta have subsided and are too low to support shallow waters inhabited by pondweeds, and thus cannot be readily restored. The greatest subsidence has occurred in the Central and West Delta Ecological Unit. A comprehensive long-term program would be developed to reverse this process. Changes in land use management, and use of suitable dredged materials or other "natural materials" should be implemented to restore land elevations to suitable ranges.

Restoration efforts should focus on those leveed lands that have not yet been subjected to severe subsidence. Prime candidates are existing managed marshes and salt ponds adjacent to San Pablo and Suisun Bays. Leveed agricultural lands and some industrial lands adjacent to Suisun Bay can be readily restored to the aquatic habitat plant community.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Many programs and projects aim to protect, restore, and enhance wetland and open water habitats in the San Francisco-San Joaquin Bay-Delta estuary. These include:

- Bay Area Aquatic Habitats Planning Group;
- Cache Creek Corridor Restoration Plan;
- California Wetland Riparian Geographic Information System Project;
- Governor's California Wetland Conservation Policy;
- Inland Wetlands Conservation Program;
- Montezuma Wetlands Project;
- National Estuarine Reserve Research System;
- North Bay Initiative;
- North Bay Wetlands Protection Program;
- San Francisco Bay Regional Water Quality Control Board, and San Francisco Bay Conservation and Development Commission - Regional Wetlands Management Plan;
- San Francisco Estuary Project;
- Tidal Wetlands Species Recovery Plan;
- Wetland Reserve Program; and
- Yolo Basin Wetlands Project.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

The aquatic habitat plant community group is linked to other habitats that include open water, shallow water, emergent wetland, and riparian areas, and to associated wildlife guilds. It is also linked to physical processes that include streamflow, sediment supply, geomorphology, and tides. Secondary ecosystem functions and processes that are linked with the aquatic habitat plant community group include current velocities; floodwater and sediment detention and retention; vegetation succession, overbank flooding, and floodplain inundation; and primary production. Stressors that affect this plant community group include levees, bridges, and bank protection; dredging; non-native species; dams, reservoirs, and other human-made structures; water management; gravel mining; contaminants; and human disturbance.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the aquatic habitat plant community group is to increase its amount in the Delta to provide habitat for pondweeds with floating and submerged leaves as well as improved foraging and resting habitat for water birds, particularly diving ducks, and help to restore and maintain the ecological health of the terrestrial and aquatic resources in and dependent on the Delta.

The general target for restoring the aquatic habitat plant community group is to provide 500 acres in the Sacramento-San Joaquin Delta Ecological Zone and 500 acres in the Suisun Marsh/North San Francisco Bay Ecological Zone.

The following actions would help to achieve targets for the aquatic habitat plant community group restoration:

- Restore perennial shallow water habitat in concert with restoration of tidal brackish and freshwater marsh and tidal riparian plant habitat.

- Link restored areas with existing healthy habitats to provide a source of vegetative propagules and to create large contiguous areas of aquatic habitat.

- Focus restoration effort on leveed lands that have not yet experienced severe subsidence, such as leveed agricultural lands and industrial lands adjacent to Suisun Bay.

- Restore permanent open-water areas by establishing elevation gradients sufficient to maintain surface water through natural groundwater or surface-water recharge, or by pumping water into lowland areas.

- Propagate restored areas with pondweeds and control invasion by exotics until the community has become established.

TIDAL BRACKISH AND FRESHWATER MARSH HABITAT PLANT COMMUNITY GROUP

INTRODUCTION

Tidal brackish marsh habitat is located along the western edge of the Delta and in Suisun marsh. Most tidal freshwater marshes in the Delta occur as narrow, fragmented bands along island levees, channel islands, shorelines and levee blowout ponds.

Tidal brackish and freshwater marshes are important habitat areas for fish and wildlife dependent on marshes and tidal shallows and support several special-status plant species. The loss or degradation of historic tidal brackish and freshwater marshes has substantially reduced the habitat area available for associated plant, fish and wildlife species. Major factors that limit this resource's contribution to the health of the Bay-Delta are related to adverse effects of wetlands conversion to agricultural, industrial, and urban uses.

The vision for tidal brackish and freshwater marsh habitats is to restore large areas of connecting waters associated with tidal emergent wetlands and their supporting ecosystem processes. Achieving this vision will assist in the recovery of special-status plant populations depending on these habitats. It will also assist in the recovery of special-status fish populations and provide high-quality aquatic habitat for other fish and wildlife dependent on the Bay-Delta. Restoring tidal brackish and freshwater marsh would also result in higher water quality and increase the amount of shallow-water habitats; foraging and resting habitats and escape cover for water birds; and rearing and foraging habitats, and escape cover for fish. The vision for this habitat type is to protect existing tidal brackish and freshwater marshes from degradation or loss and to increase wetland habitat. Achieving this vision will assist in the recovery of special-status plant, fish, and wildlife populations, and provide high-quality habitat for other fish and wildlife dependent on the Bay-Delta.

RESOURCE DESCRIPTION

Tidal brackish marshes were once continuous from San Francisco Bay into the western Delta. Most remnants of these wetlands are narrow bands along the margins of San Pablo Bay and Suisun Marsh and Bay. Tidal brackish marshes have been substantially reduced as a result of reclamation and land use conversions to agricultural uses, actions that reduced the amount of land subject to tidal flooding.

Tidal brackish marshes are important habitats for plant, fish and wildlife species that are dependent on marshes and tidal shallows. These wetland areas serve as an important transitional habitat between open water and uplands. Furthermore, tidal exchange is the primary process that supports healthy tidal brackish marshes in the Bay-Delta. Tides flush the wetland system, replacing nutrients and balancing salinity concentrations. Land management practices such as diking have isolated most of the remaining brackish marsh wetlands from tidal flows.

Five distinct plant series are found in tidal brackish marshes; each of these is briefly described below.

Pickleweed Series: Pickelweeds (*Salicornia* species) are the dominant plants in this series. Other associated plant species can include alkali heath (*Frankenia salina)*, arrow-grasses (*Triglochin* species), dense-flowered cordgrass (*Spartina densiflora)*, dodder (*Cuscuta salina)*, fat-hen (*Atriplex patula)*, jaumea (*Jaumea carnosa)*, saltgrass (*Distichlis spicata)*, saltwort (*Batis maritima)*, sea-blite (*Suaeda californica)*, and/or sea-lavender (*Limonium californicum)*.

This plant series is generally less than 5 feet tall and the canopy can be continuous or intermittent.

Saltgrass Series: Saltgrass (*Distichlis spicata)* is the sole or dominant grass in this series. Other associated plant species can include alkali cordgrass *(Spartina gracilis)*, alkali muhly *(Muhlenbergia asperifolia)*, alkali sacaton *(Sporobolus airoides)*, Baltic rush *(Juncus balticus)*, common pickleweed *(Salicornia virginica)*, Cooper rush *(Juncus cooperi)*, one-sided bluegrass *(Poa secunda)*, sea-lavender *(Limonium californicum)*, slender arrow-grass *(Triglochin concinna)*, and/or yerba mansa *(Anemopsis californica)*. Emergent alkali rabbitbrush *(Chrysothamnus albidus)* or iodine bush *(Allenrolfea occidentalis)* may be present. This plant series is generally less than 3.5 feet tall and the canopy can be continuous or intermittent.

Bulrush Series: Bulrushes (*Scirpus* spp.) are the dominant species in this series. Common plant species include California bulrush (*Scirpus californicus)*, common three-square (*Scirpus americanus)*, common tule (*Scirpus acutus)*, Nevada bulrush *(Scirpus nevadensis)*, river bulrush (*Scirpus fluviatilis)*, and saltmarsh bulrush (*Scirpus maritimus)*. Other associated plant species can include broadleaf cattail (*Typha latifolia)*, narrowleaf cattail (*Typha angustifolia)*, saltgrass (*Distichlis spicata)*, slenderbeaked sedge (*Carex athrostachya)*, southern cattail *(Typha domingensis)*, umbrella flatsedge *(Cyperus eragrostis)*, water-plantain *(Alisma plantago-aquatica)*, and/or yerba mansa *(Anemopsis californica)*. The species in this series are generally less than 13 feet tall and the cover can be continuous or intermittent.

Cattail Series: Cattails, including broadleaf cattail *(Typha latifolia)*, narrowleaf cattail *(Typha angustifolia)*, and southern cattail *(Typha domingensis)*(*Typha* spp.) are the dominant plants in this series. Associated plant species can include California bulrush *(Scirpus californicus)*, common three-square *(Scirpus americanus)*, common tule *(Scirpus acutus)*, Nevada bulrush *(Scirpus nevadensis)*, river bulrush *(Scirpus fluviatilis)*, saltgrass *(Distichlis spicata)*, saltmarsh bulrush *(Scirpus maritimus)*, slender-beaked sedge *(Carex athrostachya)*, umbrella flatsedge *(Cyperus eragrostis)*, water-plantain *(Alisma plantago-aquatica)*, and/or yerba mansa *(Anemopsis californica)*. The plants in this series are generally less than 13 feet tall and the cover can be continuous, intermittent, or open.

Common Reed Series: Common reed (*Phragmites australis*) is the dominant plant in this series. The community may include emergent shrubs and trees. However, few other species are generally present. Common reed generally grows less than 13 feet tall and the cover is typically be continuous.

Diking of historic wetlands greatly reduced the amount of tidally influenced marshes in the Delta. Reservoir operations and other water management practices that control California's inland water supplies have reduced saltwater intrusion into the Delta by retaining water during winter and releasing water during summer. These complex water management activities resulted in reduced saltwater intrusion into the Delta, thereby reducing the area that can support brackish wetlands. Preservation of the largest single area of brackish marsh habitat in California has been accomplished at Suisun Marsh through implementation of a complex water control system.

Prior to the mid-1800s, extensive areas of tidal freshwater marsh habitat occurred throughout the Central Valley, particularly in the Delta. A complex network of rivers, sloughs, and channels connected low islands and basins that supported a diverse and dense variety of freshwater marsh vegetation. This freshwater marsh vegetation supported a diversity of plant, fish and wildlife species and ecological functions. Vast areas of the Sacramento-San Joaquin Valleys were commonly flooded in winter by a slow-moving blanket of silt-laden water. Flood control activities and land settlements in the late 1800s and early 1900s led to the development of leveed Delta islands. Levees and other land uses led to the loss of freshwater marshes in the Delta. Loss of wetlands has substantially reduced habitat for wetland wildlife species in the Bay-Delta system. Freshwater marsh losses have also substantially reduced the area available for the biological conversion of nutrients in the Delta. The Delta contains insufficient wetland area to provide adequate levels of nutrient transformation, which results in lower quality water in San Francisco Bay.

The loss of freshwater marshes has substantially reduced the habitat of several plant and wildlife species. Some species have been designated as California or federal special-status species and are threatened with local extermination. At least eight special-status plant species, Suisun Marsh aster, California hibiscus, bristly sedge, Jepson's tule pea, Mason's lilaeopsis, marsh mudwort, Sanford's arrowplant, and marsh scullcap, are native to the Delta. Most of these plants are adapted to a complex tidal cycle and are typically found with more common vegetation such as tule, cattails, common reed, and a great diversity of other herbaceous plant species. Changes in habitat conditions have allowed the invasion of hundreds of non-native weedy plant species. Some of these species, such as water hyacinth, now clog waterways and irrigation ditches and reduce overall habitat quality for native plants and wildlife. Over 50 species of birds, mammals, reptiles, and amphibians use freshwater marshes in the Delta. Populations of some wildlife species that are closely dependent on freshwater marshes, such as the California black rail, giant garter snake, and western pond turtle, have been substantially reduced in the Delta and designated as special-status species. A few wetland-associated species, such as waterfowl and egrets, have successfully adapted to foraging on some types of Delta croplands converted from historic wetland areas.

Isolating wetlands from tidal flows and removing Delta island freshwater marshes changed the ecological processes that support wetlands. Removing the perennial water and vegetation from the organic soils of Delta islands resulted in soil oxidation and, subsequently, the subsidence of the interior islands. Loss of these tidal flows to islands has reduced habitat for native species of fish, plants, and wildlife; reduced water quality; and decreased the area available for floodwater dispersion and suspended silt deposition.

High tidal velocities in confined Delta channels continue to erode remaining freshwater marshes at a greater rate than habitat formation. Continued erosion reduces the amount of freshwater marshes and changes the elevation of the land. Elevation affects the types of plant species that can grow depending on a species' ability to tolerate flooding. Flood protection and levee maintenance continue to impair wetland vegetation and prevent the natural reestablishment of freshwater marshes in some locations.

Wind, boat-wake waves, and high water velocities in confined channels actively erode the soil needed to support remnant freshwater marshes. Continued erosion of existing habitat, such as midchannel islands and levees and levee berms, is currently the primary cause of habitat loss in the Delta.

VISION

Restoration of tidal brackish and freshwater marsh habitat would focus on protecting and improving important existing wetlands, such as channel islands, and restoring wetlands in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones.

Restoring tidal brackish marsh is dependent on restoring tidal flows, establishing and maintaining healthy estuarine salinity gradients appropriate, and reestablishing elevation gradients from open water to uplands. The following actions would help achieve saline emergent wetlands restoration:

- restore tidal flows to diked wetlands by breaching dikes in suitable areas;

- establish desirable estuarine salinity gradients by managing water diversions and water releases from upstream reservoirs to control seasonal freshwater inflows to the Delta;

- balance seasonal flows from reservoirs for fisheries, water conveyance, flood control, and the needs of other habitats; and

- restore a more natural elevation gradient in wetlands to allow a greater diversity of native saline plant species, including special-status species, that are adapted to different elevations and provide a broader range of habitats for wildlife.

Enhancing and increasing tidal brackish marsh habitat would also help to increase water quality. Areas restored to tidal flow will contribute to the aquatic foodweb of the Bay-Delta and provide fish rearing habitat. Restoring tidal brackish marshes would improve the ecological value of adjacent associated habitats, including tidal aquatic habitats, and will provide an important transitional zone between open water and uplands.

Other habitat restoration efforts will be directed toward reestablishing native plant species, controlling competitive weedy plants, increasing the quality of adjacent upland habitats to provide refuge for wildlife during high tides, and modifying land use practices that are incompatible with maintaining healthy wetlands. Restoring saline emergent wetlands would be coordinated with restoration of other habitats to increase overall habitat values. For example, saline emergent wetland greatly increases wildlife habitat quality of deep and shallow open-water areas and adjacent grasslands.

To prevent further loss of existing freshwater marshes, erosion rates must be reduced. Inchannel islands and levee berms are of particular concern. Erosion losses could be offset by allowing deposition and wetland establishment. Wetlands erosion could be reduced by reducing boat speeds where wetlands are subject to boat-wake-induced erosion (e.g., Snodgrass Slough). Constructing protective structures around eroding channel islands would weaken wave action (e.g., wave barriers and riprap groins) in a way that retains habitat value for fish and wildlife. Protecting inchannel islands from further erosion and connecting with larger islands would provide greater protection for this unique habitat.

Restoring freshwater marsh habitat is dependent on local hydrological conditions (e.g., water depth, water velocity, and wave action); land elevation and slope; and the types and patterns of sediment deposition. The approach to restoring freshwater marshes would include:

- reestablishing the hydraulic, hydrologic, and depositional processes that sustain freshwater marshes and inchannel islands;

- restoring a full spectrum of wetland elevations to allow the establishment of a greater diversity of plant species, including special-status species adapted to different elevations within the tidal or water (nontidal sites) column; and

- providing a broader range of habitats for wildlife.

Restoration of freshwater marshes would be coordinated with restoration of other habitats to increase overall habitat values. Restoration would also include reestablishment of the full diversity of freshwater marsh plant associations to ensure that the habitat needs of special-status and other species that are dependent on specific vegetation associations are met.

Protecting and restoring freshwater marshes could be accomplished by implementing elements of existing restoration plans such as Central Valley Habitat Joint Venture; expanding State and federal wildlife areas to create additional wetland complexes; improving management of existing and restoring additional freshwater marshes on private lands; and reestablishing connectivity between the Delta and Delta islands, and between channels with their historic floodplains.

Major opportunities exist for restoring tidal freshwater marshes. Actions that would help restore fresh emergent wetlands include:

- Setbacks or breaches of island levees to allow water flows to naturally reestablish wetlands.
- Increase land elevations in the interior of Delta islands where subsidence has lowered land elevations below tidal emergent wetlands
- Use substrate materials to create levee berms at elevations necessary for freshwater emergent vegetation
- Modify, where consistent with flood control objectives, levee vegetation management practices to allow wetland vegetation to naturally reestablish.
- Reintroduce native wetland plants into suitable sites.

These protection and restoration strategies could be implemented by:

- establishing cooperative efforts between government and private agencies to coordinate the efficiency of implementing existing restoration strategies and plans;
- developing and implementing alternative land management practices on public lands to improve wetland habitat quality or promote habitat recovery, and provide incentives to private landowners to implement desirable land use practices;
- establishing additional incentive programs to encourage landowners to establish and maintain freshwater marsh wetlands; and
- protecting existing habitat areas from potential future degradation through acquisition of conservation easements or purchase from willing sellers.

Restoration of stream meander belts and the process of overbank flooding along major tributaries to the Bay-Delta as proposed in the ERPP in other ecological zones will also create the conditions necessary for the natural reestablishment of freshwater marshes elsewhere in the Central Valley.

These protection and restoration needs could be met by establishing cooperative efforts between government and private agencies. This effort would coordinate implementation of existing restoration strategies and plans; develop and implement alternative land management practices on public lands to improve wetland habitat quality or promote habitat recovery; provide incentives to private landowners to implement desirable land use practices; establish additional incentive programs to encourage landowners to create and maintain saline emergent wetlands; and protect existing habitat areas from future degradation through acquisition of conservation easements or purchase from willing sellers.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore tidal brackish and fresh emergent marsh habitat would involve cooperation with other wetland restoration and management programs. These include:

- Agricultural Stabilization and Conservation Service's Wetland Reserve Program.
- Wildlife Conservation Board's Inland Wetland Conservation Program

- restoration programs administered by Ducks Unlimited and the California Waterfowl Association

- the Suisun Marsh Protection Plan

- ongoing management of State and federal wildlife refuges and private duck clubs

- and the San Francisco Bay Wetlands Ecosystem Goals Project

Proposed ERPP targets may be adjusted to reflect goals identified by the San Francisco Bay Wetlands Ecosystem Goals Project. Restoration efforts would be conducted in cooperation with agencies or organizations with responsibility or authority for restoring wetland and aquatic habitats, including:

- U.S. Bureau of Reclamation

- California Department of Fish and Game,

- California Department of Water Resources,

- U.S. Fish and Wildlife Service,

- U.S. Army Corps of Engineers,

- and the Delta Protection Commission

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Tidal brackish and freshwater marshes are linked to other ecological elements in the Bay. Tidal exchange is an important ecological function that restores the proper salinity and nutrient balance and mixed fresh and estuarine waters.

Tidal brackish and freshwater marshes are closely linked to open water areas and upland habitats. The value of each habitat is increased by the presence and quality of the adjacent types of habitats. A variety of aquatic and terrestrial fish, wildlife and plant communities depend on healthy tidal brackish and freshwater marshes. These include Suisun Marsh aster, California hibiscus, bristly sedge, Jepson's tule pea, Mason's lilaeopsis, marsh mudwort, Sanford's arrowplant, and marsh scullcap and the salt marsh harvest mouse.

Tidal brackish marshes are impaired by reduced seasonal inflows of fresh water, land use, and loss of upland habitat, and introduction an proliferation of invasive salt marsh plant species. Stressors that have reduced the extent of fresh emergent wetlands include flood protection practices, levee construction, and the loss of tidal flow. Increased velocities in Delta channels causes erosion of wetlands and changes the elevation of the land. Wind and boat wake erosion also contribute to the loss of soil needed to support fresh emergent wetlands in area where midchannel islands and levee berms are present.

IMPLEMENTATION OBJECTIVE, TARGETS AND PROGRAMMATIC ACTIONS

The implementation objective for tidal brackish and freshwater marsh is to protect and enhance existing wetlands by restoring tidally influenced brackish and freshwater marsh areas in the Delta. The increased wetland area would expand the populations and ranges of associated special-status plant and animal species and would provide habitat for waterfowl, shorebirds, and other associated wildlife. It would also provide rearing habitat, foraging habitat and escape cover for fish.

The following action would help achieve tidal brackish marsh restoration:

- restore tidal flows to diked wetlands by breaching dikes in suitable areas;

- establish desirable estuarine salinity gradients by managing water diversions and water releases from upstream reservoirs to controls seasonal freshwater inflow into the Delta;

- balance seasonal flows from reservoirs for fisheries, water conveyance, flood control, and the need of other habitats;

- restore a more natural elevation gradient in wetlands to allow a greater diversity of native saline plants species, including special-status plant species that are adapted to different elevations and provide a broader range of habitats for wildlife.

Actions that would help restore tidal freshwater marsh include:

- setbacks or breaches of island levees to allow water flows to naturally reestablish wetland;

- increase land elevations in the interior of Delta islands where subsidence has lowered land elevation below tidal emergent wetlands;

- use of substrate materials to create levee berms at elevations necessary for freshwater marshes;

- modify, where consistent with flood control objectives, levee vegetation management practices to allow wetland vegetation to naturally establish;
- reintroduce native plants into suitable sites.

These protection and restoration strategies could be implemented by:

- establishing cooperative efforts between government and private agencies to coordinate the efficiency of implementing existing restoration strategies and plans;

- developing and implementing alternative land management practices on public lands to improve wetland habitat quality or promote habitat recovery, and provide incentives to private landowners to implement desirable land use practices;

- establish additional incentive programs to encourage landowners to establish and maintain freshwater marshes; and

- protecting existing habitat areas from potential future degradation through acquisition of conservation easements or purchase from willing sellers.

Restoration of stream meander belts and the process of overbank flooding along major tributaries to the Bay-Delta as proposed in the ERPP in other ecological zones will also create the conditions necessary for the natural reestablishment of tidal brackish and freshwater marsh habitats elsewhere in the Central Valley.

SEASONAL WETLAND HABITAT PLANT COMMUNITY GROUP

INTRODUCTION

The Bay-Delta seasonal wetland habitat plant community group includes vernal pools and seasonally flooded areas. Vernal pools are probably best described as specialized components of terrestrial (land-based) habitats and requiring specific geomorphic features. Other seasonally flooded areas may be described as areas which flood for periods that are too long to support characteristic upland vegetation. Seasonally flooded areas may occur in low grassland basins, the perimeter of the permanent marshes, and within a stream course or its floodplain. Historically, seasonal wetlands occurred throughout the Central Valley. Loss of seasonal wetland habitat, vernal pools in particular, has directly resulted in the listing of several species as threatened or endangered under the federal Endangered Species Act.

Major factors that limit the contribution of this habitat type to the health of the Bay-Delta are related to adverse effects of land conversion, and substantial reductions in seasonal overbank flooding.

RESOURCE DESCRIPTION

Vernal pools are associated with soils (claypan, hardpan) that maintain standing water after winter and spring rains. In some areas of the Central Valley, high spring flows from the rivers and creeks saturate soils. Seasonal wetlands are created when puddles or small ponds form in depressions or standing water remains in low-lying grass fields after river flows recede. Although aquatic plants can establish in areas that are frequently flooded, upland plants cannot survive.

Vernal pools are seasonally flooded depressions formed where a barrier, such as a clay pan or cemented hard pan, restricts percolation of rainwater and runoff from adjacent areas during the winter rainy season. They support a distinctive herbaceous biota adapted to periodic or continuous inundation during the wet season and desiccated soils during the dry season (Holland and Jain 1977, Holland 1978, Thorne 1984, Zedler 1987, Jones & Stokes Associates 1990). Vernal pools usually occur in depressions between small mounds or ridges in a hummocky, rolling, or reticulated landscape. They vary in size from several yards to well over 1 acre and the largest pools are really seasonal lakes, like Olcott Lake at the Jepson Prairie Preserve in Solano County. Vernal pools are common in grasslands in northern Central Valley where the natural geomorphology remains relatively unchanged.

Species commonly found as dominants in vernal pools include goldfields (*Lasthenia* spp.), navarretia (*Navarretia leucocephala*), prostrate pigweed (*Polygonum arenastrum*), coyote thistle (*Eryngium* spp.), woolly marbles (*Psilocarphus* spp.), popcorn flowers (*Plagiobothrys* spp.), downingias (*Downingia* spp.), annual hairgrass (*Deschampsia danthonioides*), and common spikerush (*Eleocharis macrostachya*). Many State- and federally listed plants, invertebrates, and wildlife, including Contra Costa goldfields (*Lasthenia conjugens*), legenere (*Legenere limosa*), western spadefoot toad (*Scaphiopus hamondii*), California tiger salamander (*Ambystoma tigrinum*), and various fairy shrimp, are native to or associated with vernal pools. In addition, a variety of birds, including migrating waterfowl, shorebirds, and ground-nesting birds such as meadowlarks, commonly use seasonal wetlands habitat.

Vernal pools are best distinguished from one another by specific geomorphic features then by plant species composition. This is because the species composition and the relative cover by each species varies not only between pools, but varies from season to season within the pools. Two vernal pool ecosystem types are recognized in the Bay-Delta region. They are northern claypan vernal pools and northern hardpan vernal pools.

Northern claypan vernal pools contain mixo-saline water to freshwater ponded over claypans. They occur on neutral to alkaline, silica-cemented hardpan soils which are often saline. They are more widespread in the south San Joaquin Central Valley but range north into the Sacramento Central Valley area. Alkaline types of claypan vernal pools are characterized by a high alkaline salt content and dominance by plant species adapted to these conditions. Alkaline pools occur on extremely salty soils such as the Pescadero clay series underlying Olcott Lake in the Jepson Prairie Preserve. Alkaline pools support common alkaline plants such as alkali heath (*Frankenia salina*), alkali mallow (*Malvella leprosa*), and alkali weed (*Cressa truxillensis*). Some special status plants found in alkaline pools include bearded popcorn flower (*Allocarya histriculus*), Solano grass (*Tuctoria mucronata*), and Colusa grass (*Neostapfia colusana*).

Northern hardpan vernal pools contain mixo-saline water to freshwater impeded by hardpans. They occur on old, acidic, iron-silica cemented soils including Corning, Redding, and San Joaquin soil series. They are typically found on old alluvial fans ringing the Central Valley.

Seasonally flooded areas play a vital role in the natural succession of plant communities. Seasonally flooded areas that maintain surface water for long periods may support herbaceous plant dominants in three recognized plant communities - cattails, bulrushes, and sedges. Historically, these emergent plant species were probably prevalent along natural stream courses where long-standing water reduced the ability of upland species to establish. These types of wetlands provide the essential building blocks for the future establishment of riparian (streambank) scrub and eventually riparian woodland. Beyond the normal river flows, wetlands probably formed where rains and high flows left areas too wet for terrestrial plants to establish. These wetland areas provide high-quality habitat for a special status plant, Sanford's arrowhead (*Sagittaria sanfordii*), and a variety of wildlife including waterfowl, other migratory birds, shorebirds, red-legged frogs, giant garter snakes, and tricolored blackbirds.

The continued existence of the seasonal wetland habitat plant community group is closely linked to overall ecosystem integrity and health. Although many species that use seasonal wetlands are migratory (e.g., waterfowl and sandhill cranes), many others have evolved (e.g., spadefoot toad, fairy shrimp, and many specialized plants) and adapted to seasonal wetlands.

The extent and quality of the seasonal wetland habitat plant community group has declined because of cumulative effects of many factors, including:

- modification of natural geomorphology such as ground leveling for agriculture and development,
- adverse effects of overgrazing,
- contamination from herbicides,
- establishment of non-native species that have an adverse effect on native wetland plants and wildlife,
- flood control and water supply infrastructure that reduces overbank flooding and floodplain size, and
- reduction of the natural underground water table that supported wetlands.

Existing wetland regulations have been in effect for several years in an attempt to prevent the further loss of wetlands. The protected status of wetlands has resulted in an extensive permitting process for construction in wetland areas.

Mitigation measures have been developed to offset loss of existing wetlands as a result of construction activities. These efforts have slowed the rate of wetland loss in many areas. Large-scale efforts in areas such as the Suisun Marsh, Grasslands Resource Conservation District, Yolo Bypass, Cosumnes River Preserve, Jepson Prairie Preserve, and Butte Sink have been successful in maintaining and restoring seasonal wetlands.

VISION

The vision for the seasonal wetland habitat plant community group is to improve the quality and extent of these habitat plant community group by restoring ecosystem processes that sustain them, preserving and enhancing their linkage to important other habitat plant community groups and reducing the effect of stressors.

Restoration of seasonal wetland habitat will focus on protecting and improving important existing wetlands, reestablishing vernal pools within and adjacent to existing ecological reserves, and restoring seasonal wetlands in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones. Seasonal wetland restoration will be coordinated with restoration of other habitats, including shallow-water and riparian woodland and scrub. Restoration would include reestablishment of the full diversity of seasonal wetland plant associations to ensure that the habitat needs of special-status and other species that are dependent on specific vegetation associations are met.

Actions that would help protect and restore seasonal wetland habitat plant communities are contained in the Vision for Seasonal Wetland habitat.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore seasonal wetland habitat plant communities would involve cooperation with other restoration programs, including:

- Upper Sacramento River Fisheries and Riparian Habitat Council,
- Suisun Marsh Protection Plan,
- California Department of Fish and Game wildlife areas,
- U.S. Fish and Wildlife Service refuges,
- Cosumnes River Preserve,
- Jepson Prairie Preserve,
- Solano County Farmland and Open Space Land Trust,
- Ducks Unlimited Valley Care Program,
- California Waterfowl Association,
- Cache Creek Corridor Restoration Plan,
- The Nature Conservancy,
- California Native Plant Society,
- Putah Creek South Fork Preserve,
- Woodbridge Ecological Reserve,
- Yolo County Habitat Conservation Plan,
- and Central Valley Habitat Joint Venture.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

The seasonal wetland habitat plant community group is linked to other ecosystem elements in the ERPP Study Area. The seasonal wetland habitat plant community group includes vernal pools and seasonally flooded areas that support many species and communities of wildlife and plants. Seasonal wetland habitat plant communities are linked to primary and secondary physical processes including geomorphology, vegetation succession, overbank flooding, and floodplain inundation. Seasonal wetland habitat plant communities are linked to stressor elements including land use, non-native species, water management, and human disturbance. Seasonal wetland habitat plant communities are linked to habitat elements including vernal pool, seasonal wetland, and emergent wetland habitats. Links to wildlife elements include the greater sandhill crane, fresh emergent wetland wildlife guild, riparian wildlife guild, shorebird and wading bird guild, waterfowl guild, and native amphibians and reptiles. Vernal pool special-status plant species is also linked to seasonal wetland habitat plant communities.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the seasonal wetland habitat plant community group is to restore and manage this habitat type in the Delta to help restore and maintain the ecological health of the aquatic resources in and dependent on the Delta: restore foodweb and floodplain processes; reduce the effects of contaminants and water management on the Delta's aquatic resources; and provide high quality habitat for plant and wildlife resources including State- and federally listed plants, invertebrates, and wildlife that use or occur in vernal pools and seasonally flooded areas.

Actions that would help protect, restore, and enhance seasonal wetlands are contained in the Vision for Seasonal Wetlands and as follows:

- implement existing restoration plans,
- expand public and private preserves and wildlife areas to create additional wetland complexes, including vernal pools and seasonally flooded areas,
- improve management of existing wetlands and restore seasonal wetlands on private lands,
- reconnect channelized streams and rivers to their historic floodplains,
- develop and implement alternative land use practices on public and private lands that will protect and improve vernal pools and seasonally flooded areas and allow existing, compatible land uses, such as seasonally-managed grazing, to continue,
- establish incentive programs to encourage landowners to establish and maintain seasonal wetlands, and
- develop vegetation management programs to enhance habitat value and reduce impacts from stressors such as introduced species.

INLAND DUNE HABITAT PLANT COMMUNITY GROUP

INTRODUCTION

Inland dune scrub is associated with inland sand dunes and is limited to the Delta in the vicinity of the Antioch Dunes Ecological Reserve. This habitat area supports two plant and one butterfly species listed as endangered under the federal Endangered Species Act. Major factors that limit this resource's contribution to the health of the Delta are related to adverse effects of sand mining, dune conversion to other land uses, dune stabilization, and land use practices that maintain the dominance of non-native plants.

RESOURCE DESCRIPTION

Antioch Dunes. Inland dune scrub is localized in areas of wind-modified stream deposits in the south and western Delta. Inland dune scrub exists between Antioch and Oakley, south of Rio Vista, and on Brannan Island. Soil information indicates that the total inland sand-dune habitat within Contra Costa, Solano, and Sacramento Counties was historically less than 10,000 acres. Remaining habitat areas are being protected. Most protected inland dune scrub is located within the Antioch Dunes Ecological Reserve and Brannan Island State Park. These protected areas represent important, but small, relictual examples of this unique habitat.

The vegetation at Antioch Dunes consists of scattered forbs and grasses that form a ground canopy. Characteristic plant species include Antioch dunes evening-primrose (*Oenotherea deltoides* ssp. *howellii*), California croton (*Croton californicus*), California matchweed (*Gutierrezia californica*), Contra Costa wallflower (*Erysimum capitatum*), devil's-lettuce (*Amsinckia tesselata*), lessingia (*Lessingia glandulifera*), nude buckwheat (*Eriogonum nudum* var. *auricalataum*), and telegraph weed (*Heterotheca grandiflora*). Individual emergent shrubs or coast live oak (*Quercus agrifolia*) trees may be present over the ground canopy. The ground layer is generally open, and annual plants are seasonally present. The low nutrient conditions of the soils and natural instability of dune sands limit the amount of vegetation that establishes on the inland dunes.

Direct and indirect disturbances are reducing the extent and health of inland dune scrub habitat and its associated plants and animals. Sand mining directly removes habitat. Urban development has moved onto historical dune habitat and changed wind-flow patterns. Excessive foot traffic, off-road vehicle traffic, and grazing disturb dune surfaces, which makes dunes more susceptible to erosion. Application of herbicides, pesticides, and fertilizers change ecological processes that may encourage or support non-native species. Structures or activities that reduce or accelerate winds, wind-disturbances, or barriers to wind-driven sand movement disrupt the process that sustain dunes. Wind patterns blow river-deposited sand into shifting dunes. Shifting sand offers little stability for establishing plant root systems. Plant species characteristic of dunes survive within a disturbance threshold. Direct disturbances inhibit the ability of dune-associated plants to establish and result in loss of plant vigor or mortality. Sand movement barriers create conditions unfavorable for establishing native dune vegetation. These types of disturbances create site conditions conducive to establishing invasive weedy plants. Non-native weeds compete with native dunes plants and reduce overall habitat quality. Continued disturbance of potentially restorable adjacent habitat could interfere with protecting and restoring additional areas of high-quality habitat by affecting dune structure and destroying buckwheat which serves as foot for the Lange's metalmark, a federally listed as endangered species, as well as the federally listed Antioch dunes evening primrose and Contra Costa wallflower.

VISION

The vision for inland dune scrub habitat is to protect and enhance existing areas and restore former habitat areas. Achieving this vision will provide high-quality habitat for associated special-status plant and animal populations.

Restoration of inland dune scrub would focus on protecting and improving important existing habitat areas. Historic inland dunes adjacent to existing ecological reserves in the Sacramento-San Joaquin Delta Ecological Zone would be reestablished. Protecting and restoring inland dune scrub habitat would begin by identifying areas that are not currently managed for their resource values. Appropriate methods to protect and restore identified areas would be developed. Protected habitat areas would be evaluated to determine effective restoration management practices to increase habitat value. The results of these evaluations would determine how habitat would be protected and restored. For example, importing sand from areas proposed for development into low-quality areas proposed for restoration will provide important natural substrate that will increase the restoration potential. Management of the inland dune areas that are currently protected should focus on maintenance of the natural conditions to assure the natural dune ecosystem process is continued.

Reduction of stressors will be the key in establishing a long-term protection programs. In protected areas, management would include reducing human access to dune areas. Development of small boardwalks will reduce human disturbance in areas where recreational access or interpretive trails are needed. Access to the dunes by motorized or other vehicles would be prevented except as part of restoration and enhancement activities. Management activities would include exotic weed plant species removal and habitat enhancement to allow the establishment of native inland dune species. Use of herbicides, pesticides, and fertilizers would be eliminated except if it is necessary for specific non-native weedy plant species removal.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore inland dune habitat will involve cooperation with programs managed by the Antioch Dunes National Wildlife Refuge. Cooperation from agencies with responsibility or authority for restoring inland dune habitat will be solicited. These include:

- California Department of Fish and Game,
- U.S. Fish and Wildlife Service,
- U.S. Army Corps of Engineers, and
- Delta Protection Commission.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Inland dune scrub habitat is limited to the area near the Antioch Dunes Ecological Reserve. This type of habitat is important for two plant and one butterfly species listed as endangered under the federal Endangered Species Act.

It is adversely affected by human caused actions that contribute to erosion and spread of non-native species.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for inland dune scrub habitat is to improve low- to moderate-quality Delta inland dune habitat to support special-status plant and animal species and other associated plant and wildlife species. Managing protected areas could include reducing disturbance of dunes and dune vegetation. This could be accomplished by reducing vehicle and pedestrian access to dune areas. Protective structures, such as small boardwalks could be built. These actions would reduce habitat disturbance while maintaining recreational access. The following actions would help restore inland dune habitat:

- remove barriers to wind-driven sand-dune movement to increase the area that would be available for natural expansion of the sand-dune base.

- import sands from areas being developed or clean sand dredged from Bay-Delta channels to increase restoration potential and dune area.

- control non-native weeds to recreate conditions suitable for reestablishment of native dune plants.

- reduce the use of herbicide, pesticides, and fertilizers that adversely effect native dune vegetation and wildlife.

Dune habitat protection and restoration strategies could be implemented through cooperative efforts with existing ecological reserves. Restoration efforts should focus on implementing existing protection and restoration programs, establishing cooperative agreements with land management agencies, and establishing conservation easements of purchasing land from willing sellers.

TIDAL RIPARIAN HABITAT PLANT COMMUNITY GROUP

INTRODUCTION

The tidally influenced shorelines of rivers and the Delta are often vegetated with woody riparian trees and shrubs. The structure of this riparian vegetation can be like that of a forest, woodland, or scrub or may be a mosaic of these formations. Riparian vegetation supports a great diversity of wildlife species and serves as important habitat for a variety of resident and migratory songbirds. Riparian vegetation also shades riverine aquatic habitat which is important habitat for many species of fish, waterfowl, and wildlife.

Major factors that limit these plant communities' contribution to the health of the Bay-Delta include historic riparian vegetation loss or degradation and nearshore aquatic habitat alteration from channelization, stabilization of channel banks with riprap, construction of levees, and control of flows.

Restoring riparian vegetation will involve reactivating or improving natural physical processes. Natural streamflows, stream meanders, and sediment transport create and sustain these vegetation types and increase the complexity and structural diversity of the habitat. Natural sources of gravel and other sediments along rivers and floodplains provide materials needed to create and sustain healthy riparian vegetation. Where improvements to physical processes do not adequately restore riparian vegetation, direct modification may be necessary to restore vegetation to its target acreage and quality.

A major increase in tidal riparian plant community groups will improve the foodweb and provide important habitat for threatened and endangered terrestrial wildlife species, such as the yellow-billed cuckoo and Swainson's hawk. More extensive and continuous riparian vegetation cover on along rivers and in the Delta will stabilize channels; help to shape submerged aquatic habitat structure; benefit the aquatic environment by contributing shade, overhead canopy, and instream cover for fish; and reduce local water temperatures. More extensive and continuous riparian vegetation associated with woody debris (branches and root wads) and leaf and insect drop in shallow aquatic habitats will increase the survival and health of juvenile salmonids and resident Delta native fish. Achieving this objective will also greatly enhance the scenic quality and recreational experience of the Delta and its waterways.

RESOURCE DESCRIPTIONS

Tidal riparian habitat includes several plant community groups. Environmental factors such as substrate, hydrology, and degree of salt water influence determine which plant community group will occur in a given area. The plant community groups that comprise tidal riparian habitat include black willow, sandbar willow, white alder, buttonbush, Mexican elderberry, and valley oak series.

Historically the Central Valley floor had approximately 922,000 acres of riparian vegetation (Katibah 1984) supported by a watershed of more than 40,000 square miles. Today, approximately 100,000 acres of riparian forest remain. About half of this riparian habitat is in a highly degraded condition, representing a decline of 90% (Katibah 1984). The Sacramento River once supported 500,000 acres of riparian forest; it now supports 10,000 - 15,000 acres, or just 2-3% of historic levels (McGill 1979, 1987). From about 1850 to the turn of the century, most of the forest was destroyed for fuel as a result of the Gold Rush and river navigation, and by large agricultural clearing. Additional clearing in the early and mid 1900's coincided with the aftermath of flood control reservoir and levee projects.

These projects allowed for the clearing of floodplain riparian vegetation for orchards, crops, flood bypasses, and urban areas. Similar activities have occurred on the San Joaquin River and other rivers in the Central Valley.

Riparian areas along rivers within the Delta, and areas within the Delta itself, are influenced by the daily ebb and flow of the tide in the Pacific Ocean. Six distinct plant series are found within these tidal riparian areas: black willow series, narrowleaf willow series, white alder series, buttonbush series, Mexican elderberry series, and valley oak series. These six series are briefly described below.

Black Willow Series: In the black willow series black willow is the sole or dominant woody plant that forms a forest or shrubland. In this series black willow can be a tree or a shrub depending on frequency or severity of disturbance, or the seral stage of the site. Other trees occasionally found in the canopy include California sycamore, Fremont's cottonwood, white alder, and Oregon ash. Other shrubs that may be present in the black willow series include other species of willow, mulefat, Mexican elderberry, and Himalaya berry. The herb layer in black willow series can vary greatly depending on substrate conditions and site hydrology. (Sawyer et al. 1996)

Black willow series is typically found at sites that are seasonally flooded or saturated with freshwater along low-gradient depositions along rivers, streams, or sloughs. Black willow series intergrades with tidal brackish and freshwater marsh habitats and with narrowleaf willow series, white alder series, and buttonbush series.

Narrowleaf Willow Series: In the narrowleaf willow series narrowleaf willow is the sole or overwhelmingly dominant shrub in the canopy. Other trees or shrubs infrequently found in the canopy include other species of willow, Fremont's cottonwood, and white alder. The herb layer in narrowleaf willow series is usually sparse or absent because of the frequent scouring from flood events and the dense shade provided by the shrubs.(Sawyer et al. 1996)

Narrowleaf willow series often occurs at sites along the margins of rivers that are continuously disturbed by sediment deposition. Older stands narrowleaf willow series are typically found on sites that are former sandbars that have been isolated from the main channel of a waterway either through channel migration or as a result of flood control. Narrowleaf willow series intergrades with tidal brackish and freshwater marsh habitats in some areas and with black willow series, white alder series, and buttonbush series.

White Alder Series: In the white alder series white alder is the sole or dominant tree in the canopy. Other trees that may be present include California sycamore, Oregon ash, or California box-elder. Depending on the level of flooding in this series the shrub layer can be dense to sparse. The ground, or herb, layer in white alder series can be variable, however, it is typically sparse in the Central Valley. (Sawyer et al. 1996)

White alder series occurs along the banks of rivers typically in areas that experience high energy intermittent flooding. White alder series typically is best developed along the low-flow margins of rivers and streams. White alder series intergrades with black willow series, narrowleaf willow series, and valley oak series.

Buttonbush Series: In the buttonbush series buttonbush is the dominant shrub in the canopy with occasional shrubs of red osier dogwood, narrowleaf willow, or other willows also present. Buttonbush series typically forms extensive dense canopies at the water's edge and typically has a sparse ground layer. (Sawyer et al. 1996)

Buttonbush series occurs along intermittently flooded and seasonally saturated freshwater sites along rivers or sloughs. Buttonbush series intergrades with black willow series, narrowleaf willow series, and tidal brackish and freshwater marsh habitat plant communities.

Mexican Elderberry Series: Mexican elderberry is often the dominant shrub in the canopy of Mexican elderberry series. Other shrubs that may occur in this series include California wild grape, narrowleaf willow, Oregon ash, and coyote brush. Occasional Fremont's cottonwood or valley oak trees may also be present. Mexican elderberry is a species that also frequently occurs in valley oak series. The ground layer in Mexican elderberry series is variable but often consists of non-native grasses and herbs. (Sawyer et al. 1996)

Mexican elderberry series typically occurs on high floodplains or low terraces of rivers and streams. These sites experience infrequent flooding but do have seasonally high water tables. Mexican elderberry is the host plant for the Valley elderberry longhorn beetle, a federally listed threatened species. Mexican elderberry series intergrades with valley oak series and older stands of narrowleaf willow series that occur on abandoned floodplains.

Valley Oak Series: In Valley oak series valley oak is the sole or dominant tree in the canopy. In valley oak series that occurs on the high floodplains and low terraces of rivers other tree species that may be present include California sycamore, Fremont's cottonwood, and Oregon ash. The shrub layer in valley oak series is typically sparse. Common shrubs include poison oak, Mexican elderberry, and occasional willows in wetter sites. Lianas of California wild grape growing into the canopy are common in this series. The ground layer in this series is typically grassy and is often dominated by native perennial grasses where extensive ground disturbance has not occurred.

Valley oak series typically occurs on the high floodplains and low terraces of rivers and streams. These sites are infrequently or frequently flooded for relatively short durations. Valley oak series intergrades with Mexican elderberry series and infrequently with older stands of narrowleaf willow series.

In general, tidal riparian vegetation is healthiest where ecosystem processes are in the most unaffected natural state. These unaffected sites are also the most resilient to human and natural disturbance. Ecosystem processes that are integral components of tidal riparian vegetation include sediment transport, deposition, and scour. These components support the succession and regeneration of riparian vegetation promoting its continued existence and ensuring continued habitat benefits for the aquatic environment. Riparian vegetation serves many important ecological functions. Riparian vegetation absorbs nutrients and produces primary (plant) and secondary (invertebrate) biomass at very high rates. This biomass feeds numerous fish and wildlife species. Birds and small mammals nest and take cover in the protective foliage of trees and shrubs. Trees also shade and cool floodplains and channels. Water velocities are slowed by riparian vegetation, allowing sediment to settle and create new landforms. Riparian foliage also stabilizes channels and banks, thereby rendering the characteristic geomorphology of estuaries, rivers, and streams.

Primary stressors affecting tidal riparian vegetation include:

- channel straightening and clearing
- levee construction and bank hardening to protect bridge abutments and diversion structures (e.g. with rip-rap);
- instream gravel mining and riparian zone grazing;
- flow modifications affecting sediment transport and riparian plant germination;
- removal, burning, and fragmentation of mature riparian vegetation; and
- loss of sediment and bedload from watershed sources upstream of dams.

Other stressors that affect tidal riparian vegetation include (listed in increasing importance and magnitude):

- human set fires along riparian corridors;
- new expansion of orchards and vineyards into the riparian floodplain;
- displacement by invasive non-native trees and shrubs (e.g. giant reed and black fig);
- unusually high summer stage in rivers that supply increasing demand for downstream water diversions;
- groundwater lowered below the root zone, and
- expanded clearing of channel vegetation in response to recent flood events that called into question the capacity of levee-confined rivers and streams.

Most stressors have an indirect but lasting effect on riparian vegetation. These stressors can affect the ability of riparian vegetation to recover following disturbance and can reduce the overall quality of the habitat. Collectively, these stressors have substantially reduced the quality and resilience of tidal riparian vegetation, thereby diminishing their effectiveness in providing for the life cycle requirements of fishes of the Delta and Sacramento and San Joaquin Rivers and their tributaries.

VISION

The vision for tidal riparian vegetation is to protect and increase its area and quality. Achieving this vision will assist in the recovery of special-status fish, wildlife, and plant populations and provide high-quality habitat for other fish, wildlife, and plants dependent on the Bay-Delta. The vision includes restoring native tidal riparian plant communities on both the less frequently flooded higher floodplain elevations and lower frequently flooded floodplain and streambanks.

The simple preservation of remaining natural riparian vegetation will not ensure the diversity, and resilience of these habitats. Many remnant natural sites no longer have all the physical processes necessary to ensure their continued existence and habitat value. Additionally, remaining natural riparian areas are in many cases highly fragmented and disturbed reducing their overall habitat value. Most riparian vegetation restoration projects in the Central Valley have been implemented on a relatively small scale, primarily as mitigation for project impacts or as infill of existing protected preserves.

Where natural physical processes are intact, or created through active land and water management, suitable conditions for the restoration (e.g. natural colonization or active restoration) of riparian vegetation will exist. Even partial restoration or simulation of natural physical processes will amplify ecosystem processes and resultant habitat quality. Rivers and Delta estuaries where natural fluvial processes and landforms are relatively intact need to be identified and highlighted as potential reserves of riparian vegetation.

Successful restoration of riparian vegetation depends on the recovery or simulation of natural fluvial processes and landforms. Revegetating and artificially altering stream channels will be considered only where overwhelming limitations prevent natural recovery of these physical processes and ecosystem functions.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to achieve the vision for tidal riparian habitat communities may involve coordination with other programs. These include:

- U.S. Army Corps of Engineers' proposed reevaluation of the Sacramento River flood control project and ongoing bank protection project, including more comprehensive floodplain management and river ecosystem restoration opportunities;

- proposed riparian habitat restoration and floodplain management and riparian restoration studies for the San Joaquin River, including potential new flood bypass systems and expanded river floodplains on lands recently acquired by State and federal agencies and land trusts;

- ongoing Sacramento Valley conservation planning by The Nature Conservancy and other private nonprofit conservation organizations;

- ongoing coordination efforts and programs of the Wildlife Conservation Board, including the Riparian Habitat Joint Venture;

- all county-sponsored instream mining and reclamation ordinances and river and stream management plans;

- and the California Department of Conservation reclamation planning assistance programs under the Surface Mining and Reclamation Act.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Tidal riparian vegetation is linked to the ecological health of many ERPP Ecological Zones and Units. This type of vegetation is important to many fish, wildlife, and plant species and communities. It is adversely affected by many stressors that include levee construction and maintenance, flood flow patterns, summer flow patterns, gravel mining, fragmentation of existing stands of vegetation, competition and displacement by invasive non-native species, land use conversion, flood control activities, and lowered groundwater levels.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for tidal riparian vegetation is to restore and enhance black willow, narrowleaf willow, white alder, buttonbush, Mexican elderberry, and valley oak series along largely non-vegetated, riprapped banks of Delta island levees, the Sacramento and San Joaquin Rivers, and their major tributaries and abandoned farmland that once supported riparian vegetation. Restored riparian vegetation can provide shaded riverine aquatic cover for fish species, associated special-status plant and animal species, and other resident and migratory wildlife.

Recovery and simulation of natural physical processes and landforms will be accomplished using the following integrated steps:

- locating setback levees to expand potential riparian floodplain;

- expanding the storage, detention, and bypass capacity of the Sacramento and San Joaquin River flood control project to allow natural expansion of riparian vegetation within levees and the Sutter and Yolo Bypasses; and

- designating, acquiring title or easements for, and deliberately managing river riparian corridors throughout the Central Valley.

The following actions would restore or enhance sediment supply to rivers and streams:

- reduce bank hardening by creating meander zones and widening floodplains;

- analyze alternative approaches for water diversions and associated intake and screening facilities on the mainstem river to avoid hardening the bank in some sections of the river;

- remove small, nonessential dams on gravel-rich streams;

- eliminate mining in streams and on low floodplains near channels;

- widen bridges to broaden out-of-bank flow and eliminate the need to riprap vulnerable bridge abutments; and

- breach or remove nonessential levees restricting former tidelands that would capture sediment needed to create tidal mudflats and estuary landforms.

Opportunities for reducing riparian vegetation stressors include:

- phasing out instream gravel mining;

- designating and acquiring "stream erosion zones" to reduce the use of bank riprap and allow greater normal recolonization;

- designing biotechnical slope protection measures that allow riparian vegetation to be established within levees;

- phasing out or reducing livestock grazing in riparian zones;

- establishing conservation easements for purchase of land or using other incentives to reduce or eliminate cropland conversion or riparian forest;

- identifying levee-confined channels and banks where routine vegetation removal by local reclamation districts can be safely discontinued; and

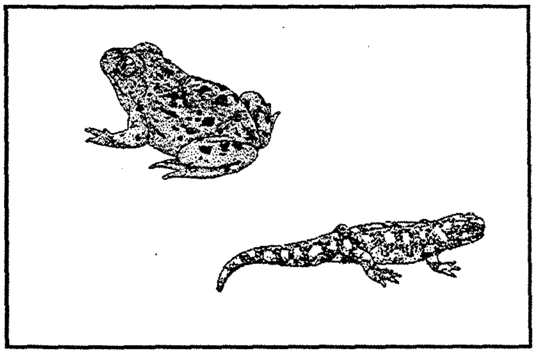
- establishing weed control programs to suppress the expansion of tamarisk, giant reed, locust, black fig, and other invasive non-native plants degrading habitat quality and native flora.

Reservoir operations will be evaluated to determine whether winter and spring releases can be augmented with flood simulation spikes every 1-10 years. Simulated flood spikes would mobilize bed and bank deposits to redistribute, sort, and clean spawning gravels and scour deep pools between riffles.

Restoring and enhancing riparian vegetation should be accomplished by eliminating the stressors and recovering or simulating the physical processes and fluvial landforms described above. Vegetation restored in this manner will be more resilient to future disturbances; require little or no long-term maintenance; be self-sustaining; and be more compatible with flood control requirements.

However, vegetation fragmentation and severe limitations of the physical environment will not allow ecosystem processes and functions to fully recover on many segments of valley streams and Delta estuaries. In these solutions, some large-scale stream channel sculpting, gravel additions, and riparian replanting may be necessary. For example, the lower Sacramento River has abandoned river floodplains and sediment is in short supply. Naturally reactivating these habitats would be nearly impossible. Restoring these habitats would require human intervention. Revegetation projects should be contemplated only where native trees and grasses many no longer germinate naturally but have a high probability of unaided survival and vigorous growth following 1-5 years of artificial irrigation.

WESTERN SPADEFOOT AND CALIFORNIA TIGER SALAMANDER



INTRODUCTION

The western spadefoot and California tiger salamander occur throughout much of the Central Valley, San Francisco Bay, and coast ranges and foothills below 3,000 feet, as well as along the coast in the southern portion of the State. Declining populations have warranted their designation as species of special concern and species of concern by the California Department of Fish and Game (DFG) and U.S. Fish and Wildlife Service, respectively. Major factors that limit these resources' contribution to the health of the Delta are related to adverse effects of conversion of seasonal wetlands and adjacent uplands to other land uses and excessive mortality resulting from introduction of non-native predators and some land use practices.

RESOURCE DESCRIPTION

Western spadefoot toad and California tiger salamander populations have declined primarily as a result of habitat loss or degradation and competition or predation from non-native species. The abundance from population to population is unknown but is influenced by the size and quality of individual habitat patches within the fragmented pockets that the species are known to inhabit.

The western spadefoot toad is primarily a lowlands species, frequenting washes, river floodplains, alluvial fans, playas, and alkali flats, but also ranges into the foothills and mountain valleys. Tiger salamanders typically inhabit scattered ponds, intermittent streams, or vernal pools that are associated with grassland-oak woodland habitat below Elevation 1500. Vernal pools covering more than 250 square feet, with fairly turbid water, provide optimal habitats. Most surface movements of the western spadefoot and California tiger salamander, including breeding activity, are associated with the onset of fall and spring rains that fill traditional breeding ponds. Warm days followed by rains or high humidity levels at night trigger reproductive and foraging activities and adults of these species sometimes appear in large numbers.

The greatest threat to the continued existence of both species is habitat loss and competition by non-native species. Habitat loss is a result of increased urbanization and conversion of native grasslands to agriculture. The spadefoot and salamander may be found in high densities in isolated areas but adjacent breeding habitat is increasingly being converted for other uses.

Introduction of predatory fish and bullfrogs in known breeding ponds is also an important factor attributed to the decline of these species. Juvenile and bullfrogs can prey on larvae and terrestrial forms of these native species. Other important stressors that affect the spadefoot and salamander are rodent control activities, which reduce the availability of summer estivation (burrowing) sites. The use of rodent burrows may be more important for the California tiger salamander than for western spadefoot because spadefoots can build their own burrows and also use other appropriate niches. Research on the extent and necessity of burrow use by both species would be valuable. In addition to rodent control activities, development of roads between breeding ponds and terrestrial habitats, resulting in deaths from automobiles during the species' migrations, has also contributed to the decline.

VISION

The vision for the western spadefoot and the California tiger salamander is to assist in the recovery of these species in the Bay-Delta. Achieving this vision will contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of land and water in the Bay-Delta.

Protecting and restoring existing and additional suitable aquatic, wetland, and floodplain habitats and reducing the effect of other factors that can suppress breeding success will be critical to the recovery of the western spadefoot and California tiger salamander. Restoration of vernal pool habitats in the Sacramento-San Joaquin Delta Ecological Zone will help recover this species by increasing habitat quality and area. Restoration of ecosystem processes and habitats in other ecological zones will also allow natural floodplains, meander corridors, seasonal pools, and vernal pools to develop that will assist in the recovery of populations of these species elsewhere in their range.

Implementing guidelines developed by DFG for vegetation, grazing, traffic, and pest management would increase these species' reproductive success and reduce the level of mortality from unnatural sources. These guidelines could be implemented through cooperative agreements with land management agencies and organizations and development and implementation of incentive programs to encourage land use practices that improve habitat conditions for and reduce mortality on these species.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Wetland restoration and management programs which contribute to restoration or maintenance of vernal pools that would improve habitat for the western spadefoot and California tiger salamander include:

- the Agricultural Stabilization and Conservation Service's Wetland Reserve Program, and
- the Wildlife Conservation Board's Inland Wetlands Conservation Program.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration of the toad and salamander populations is integrally linked with restoration of riparian and wetland habitat in the Central Valley.

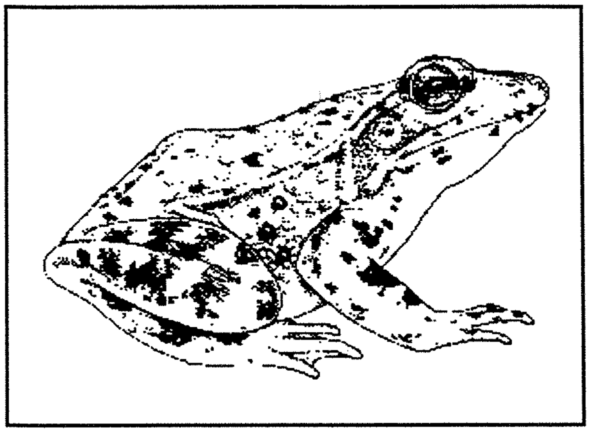
IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the western spadefoot toad and California tiger salamander is to assist in the recovery of these special-status species in the Bay-Delta in order to contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of water in the Bay-Delta.

The general target for western spadefoot and California tiger salamander are to increase the population size of each species.

General programmatic actions that will assist in reaching the targets include:

- protecting existing habitats from urbanization and conversion to irrigated pasture,
- improve degraded habitats,
- increase vernal pool habitats in the Central Valley;
- reduce the use of herbicides that adversely affect western spadefoot and California tiger salamander and their habitats;
- reduce mowing, to the extent feasible, to control vegetation and livestock grazing near occupied seasonal wetlands from October to March;
- reduce traffic, where feasible, on roads crossed by these species during migration periods;
- develop alternative control measures to replace the use fumigants to control rodents; and
- drain waterways used by the spadefoot and salamander during the periods when these species are dormant could be beneficial by reducing populations of non-native predatory fish and bullfrogs.



INTRODUCTION

The California red-legged frog is California's largest native frog. Its habitat is characterized by dense, shrubby riparian vegetation associated with deep, still, or slow-moving water that supports emergent vegetation. The distribution and population of this species has declined substantially, primarily as a result of habitat loss or degradation and excessive predation. The loss of habitat and declining condition of the species' population have warranted its listing as threatened under the federal Endangered Species Act and a Species of Special Concern by DFG. Major factors that limit this resource's contribution to the health of the Delta are related to adverse effects of the loss or degradation of critical wetland and riparian habitats and the introduction of non-native predators.

RESOURCE DESCRIPTION

The California red-legged frog historically occurred throughout the Central Valley and now exists only in small isolated populations scattered throughout its historical range. Its current range is chiefly west of the Cascade-Sierra crest from Redding in Shasta County, California, to northwest Baja California. Small populations still exist in the Central Valley and Sierra Nevada, but numbers appear to be declining in both places. Reasons for the decline of this species include the degradation and loss of critical wetland breeding and adjacent terrestrial habitats.

Human-caused stressors add to the species decline. In occupied species-areas, some agricultural practices, such as disking, mowing, burning, and pest control, result in direct mortality or degradation of habitat. The introduction of non-native fish, bullfrogs, and crayfish, all of which prey on larval, juvenile, or adult red-legged frogs increases the threat to the survival of this species. Some introduced predatory fish are large enough to injure some adults and eat juvenile red-legged frogs. The only reasonably protected population in the Central Valley is the Corral Hollow Ecological Reserve. However, this reserve is currently threatened by siltation from off-road vehicle use and livestock grazing.

VISION

The vision for the California red-legged frog is to assist in the recovery of this federally listed threatened species. Achieving this vision will contribute to the overall species richness and diversity and to reduce conflict between protection for this species and other beneficial uses of land and water in the Bay-Delta.

Protecting existing and restoring additional suitable aquatic, wetland, and riparian habitats and reducing mortality from non-native predators will be critical to achieving recovery of the California red-legged frog. Restoration of aquatic, wetland, and riparian habitats in the Sacramento-San Joaquin Delta Ecological Zone will help in the recovery of this species by increasing habitat quality and area. Establishing emergent vegetation (*Salix* sp., *Typha* sp., and *Scirpus* spp.) in canals, side channels, and backflow pools would provide breeding habitat, forage and escape cover for the California red-legged frog. Establishing these habitats in each ecological unit of the Sacramento-San Joaquin Delta Ecological Zone would create migration corridors by linking habitat areas.

Restoration of ecosystem processes and habitats in other ecological zones will also allow natural floodplains, stream meanderings, and seasonal pools to develop that will assist in the recovery of population elsewhere in the red-legged frog's range. Restoring optimal red-legged frog habitat will also reduce its susceptibility to predation and will reduce suitable habitat conditions for non-native predators.

California red-legged frog cannot be adequately restored to the Central Valley or the foothill areas without re-introduction. Recovery strategies should focus on property acquisition to preserve areas where the frog is present and to conduct detailed surveys in the western valley and Sierran foothills for remnant populations. Bullfrog predation is a major concern and focused predator management should be developed and implemented on a case-by-case basis in areas identified as important to frog populations. Reintroductions on State and Federal refuge lands with a predator management scheme should be considered.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Wetland restoration and management programs that would improve habitat for the California red-legged frog include:

- the Agricultural Stabilization and Conservation Service's Wetland Reserve Program,
- the Wildlife Conservation Board's Inland Wetlands Conservation Program,
- restoration programs administered by Ducks Unlimited and the California Waterfowl Association, and
- ongoing management of State and federal wildlife refuges and private duck clubs.

Restoration efforts will be conducted in cooperation with agencies or organizations with responsibility or authority for restoring wetland aquatic habitats including:

- California Department of Fish and Game,
- California Department of Water Resources,
- U.S. Fish and Wildlife Service,
- U.S. Army Corps of Engineers, and
- Delta Protection Commission.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration of the red-legged frog populations is integrally linked with restoration of riparian and wetland habitat in the Central Valley.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

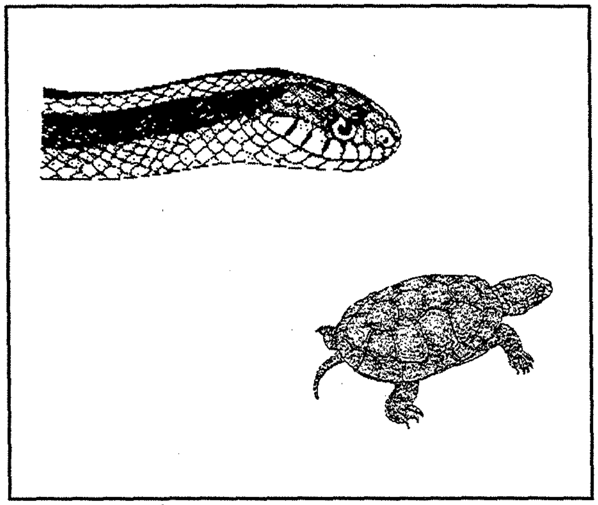
The implementation objective for the California red-legged frog is to assist in the recovery of this federally listed threatened species. Recovery of the California red-legged frog would contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

The general target is to increase the population size and distribution of the red-legged frog.

General programmatic actions to assist in reaching the target include:

- acquire land to preserve areas where frogs are present,
- develop predator (bullfrog) control programs,
- increase wetland and riparian habitats in the Central Valley;
- reduce the use of herbicides that adversely affect red-legged frog and their habitats; and
- use fumigants to control rodents from only October to March in known occupied habitats.

GIANT GARTER SNAKE AND WESTERN POND TURTLE



INTRODUCTION

The giant garter snake is a species that lives in the Central Valley of California. It inhabits sloughs, low-gradient streams, marshes, ponds, small lakes, agricultural wetlands, and other waterways, where it feeds on small fish and frogs during the active season. Populations of giant garter snake are found throughout much of the ERPP study area including: the Feather River/Sutter Basin, Colusa Basin, Butte Basin, Yolo Basin, East Side Delta Tributaries, American River Basin, and portions of the Sacramento-San Joaquin Delta Ecological Zones. The status of giant garter snake in the San Joaquin Valley is unknown. The distribution and population of these species has declined substantially, primarily as a result of the loss or degradation of wetlands and nearby uplands. The loss of habitat and declining condition of these species' populations has warranted the listing of the giant garter snake as threatened under the State and federal Endangered Species Acts and the western pond turtle being designated as a species of concern by U.S. Fish and Wildlife Service (USFWS) and a Species of Special Concern by California Department of Fish and Game (DFG).

Major factors that limit these resources' contribution to the health of the Delta are related to adverse effects of conversion of aquatic, wetland, riparian, and adjacent upland habitats to other land uses and land use practices that degrade the value of otherwise suitable habitat areas.

RESOURCE DESCRIPTION

The western pond turtle inhabits ponds, rivers, streams, lakes, marshes, and irrigation ditches with rocky or muddy bottoms. Dense cover and exposed basking sites are important components of these wetland habitat types. The western pond turtle inhabits every region of California except drainages on the eastern slope of the Sierra Nevada. Population densities vary, however, and are highly influenced by the quality of isolated habitats. A disproportionately large percentage of giant garter snake and western pond turtle populations are adults, indicating poor reproductive success.

Historic habitat areas used by these species have been substantially reduced as a result of converting land for agriculture, urban, or industrial uses or degraded as a result of ongoing land-use practices. Remaining habitat areas, such as ponds, rivers, streams, lakes, marshes, and irrigation ditches, are largely fragmented. Associated uplands, used for reproduction and hibernation, are largely unavailable. Upland habitats adjacent to aquatic habitats are now mostly isolated in small riparian bands along the tributaries that supply water to the Sacramento and San Joaquin Rivers and along canals with small levees.

Because much of the original habitat used by these species has been lost, irrigation canals and ditches (especially canals with nearby vegetation) now provide important replacement habitat for these species. Rice farming makes up a significant portion of the agricultural activity in the Sacramento Valley, and drainage ditches associated with rice farming practices provide much of this surrogate habitat. Adjacent breeding and hibernating cover, however, is often limiting for these species.

Other factors that limit these species populations include:

- some agricultural practices (e.g., disking, mowing, burning, and applying herbicides and rodenticides) that degrade habitat or cause mortality;
- introduced large predatory fish that prey on juveniles and injure adults; and
- mortality caused by flooding of hibernation sites during heavy rains, floods, or for waterfowl.

VISION

The vision for the giant garter snake and western pond turtle is to assist in their recovery in order to contribute to the overall species richness and diversity. Achieving this vision will reduce the conflict between protection for this species and other beneficial uses of land and water in the Bay-Delta.

Protecting existing and restoring additional suitable wetland and upland habitats will be critical to achieving recovery of the giant garter snake and western pond turtle. The Ecosystem Restoration Program Plan's (ERPP's) proposed restoration of aquatic, wetland, riparian, and upland habitats in the Sacramento-San Joaquin Delta Ecological Zone will help in the recovery of these species by increasing habitat quality and area.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Restoration projects to improve upland and wetland agriculture and seasonal wetland and riparian habitats would be closely linked to the restoration of these species. The American River Basin is ecologically important because it contains the most stable populations of giant garter snakes. The Biological Resources Division of the USGS is presently studying stable populations of giant garter snakes that occur outside the American River Basin. These include populations in the Colusa Basin (Sacramento and Colusa National Wildlife Areas), the Badger Creed areas of the Cosumnes River Preserve, and the Gilsizer Slough area of the Sutter Basin. Restoration and agricultural improvements will be developed for implementation both north and south of the Delta.

Efforts to recover giant garter snake and western pond turtle populations will involve cooperation and support from other established programs aimed at restoring habitat and populations.

Wetland restoration and management programs that would improve habitat for these species include the Agricultural Stabilization and Conservation Service's Wetland Reserve Program, the Wildlife Conservation Board's Inland Wetlands Conservation Program, restoration programs administered by Ducks Unlimited and the California Waterfowl Association, and ongoing management of State and federal wildlife refuges and private duck clubs. Restoration efforts will be conducted in cooperation with agencies or organizations with responsibility or authority for restoring wetland and aquatic habitats, including DFG, California Department of Water Resources, USFWS, U.S. Army Corps of Engineers, and the Delta

Protection Commission. USFWS is also preparing a recovery plan for the giant garter snake that will establish population recovery goals.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration of ecosystem processes and habitats proposed by ERPP in other ecological zones will also allow natural floodplains, stream meanders, and seasonal pools to develop that assist in the recovery of their populations elsewhere in their historic ranges.

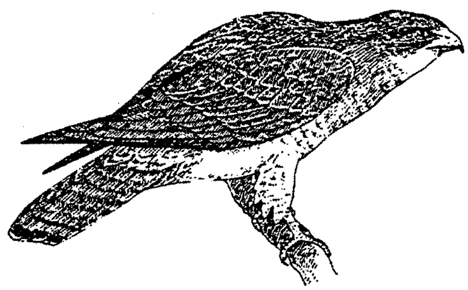
IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the giant garter snake, a federally listed threatened species, and western pond turtle, a species of special concern, is to assist in their recovery. Meeting this objective would contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of land and water in the Bay-Delta.

The general target is to increase the population size of giant garter snakes and western pond turtles.

General programmatic actions to protect occupied habitat areas include the following:

- Implement a preservation plan to protect these areas from adverse effects associated with human encroachment and recreation,
- Create canals, side channels, and back-flow pools containing emergent vegetation within the South, East, and North Delta Ecological Units of the Sacramento-San Joaquin Delta Ecological Zone to provide forage habitat and escape cover, and create dispersal corridors by linking habitat areas.
- Restore suitable adjacent upland habitat or modify land use practices to render existing uplands as suitable habitat and reestablish connectivity between wetland and upland habitat areas, provide nest and hibernation sites, and provide refuge habitat during floods.
- Create buffer zones where none currently exist to improve habitat value.



Swainson's Hawk
Threatened (State)

INTRODUCTION

Swainson's hawks occur throughout the Central Valley where riparian forest and oak savanna habitats are present. The nesting population of the Swainson's hawk has declined substantially, primarily as a result of habitat loss and degradation, reduced reproductive success, and high rates of mortality during migration and on South American wintering areas. The loss of habitat and declining condition of the species' population have warranted its listing as threatened under the State Endangered Species Act. Major factors that limit this resource's contribution to the health of the Bay-Delta are related to adverse effects of habitat loss and degradation, toxic pesticides accumulated in the foodweb on reproduction, human-associated disturbances at nest sites, and increased competition with other species for nest sites.

RESOURCE DESCRIPTION

The Swainson's hawk was common in the Central Valley at the end of the 19th century. Historical populations were estimated between 4,000 and 17,000 pairs, but declines were documented as early as the 1940s. In 1979, 110 active pairs were observed in the Central Valley with estimates of 375 pairs present throughout the State. Today, the few remaining concentrations of breeding pairs are supported within the Yolo, Sacramento, San Joaquin, Sutter, and Colusa Counties, with steadily decreasing numbers to the north and south.

Possible reasons for the Swainson's hawk's decline include

- loss or degradation of habitat on the breeding grounds,
- disturbance on the breeding grounds,
- thin eggshells from pesticide residues,
- increased competition with other species, and
- mortality during migration and on the wintering grounds in South America.

To a large degree, the decline of the Swainson's hawk can be attributed to the long-term, cumulative effects of riparian and wetland habitat conversion and degradation. A combination of changes to Central Valley area ecosystems has added to the problem. These changes include:

- the conversion of perennial grassland to agricultural uses, eliminating foraging habitat;
- urban development adjacent to waterways and nesting areas;
- incompatible land use that disrupts breeding and nesting;
- levees and bank protection that eliminate nesting habitat;

- disturbance from human activities near nest sites; and

- contaminants from agricultural runoff and pesticide use.

Excessive harvest of Swainson's hawk on South American wintering grounds is also thought to be a major factor affecting the decline of the species.

Agricultural crops, such as alfalfa, and dryland pasture provide habitat that supports a continual prey base for the Swainson's hawk. A large number of hawks may congregate near farming activities such as mowing, disking, and irrigation where prey, including some agricultural pests such as grasshoppers, is abundant. Valley oak and riparian woodlands are essential for Swainson's hawk nesting, and 78% of nest trees are located within riparian systems with adjacent foraging habitat. The Swainson's hawk typically returns to the same nest site; therefore, the preservation of nest sites is important to prevent total loss.

VISION

The vision for the Swainson's hawk is to assist in the recovery of this State-listed threatened species to contribute to the overall species richness and diversity. Achieving this vision will reduce conflict between protection for this species and other beneficial uses of land and water in the Bay-Delta.

Habitat restoration in the Sacramento-San Joaquin Delta Ecological Zone will help achieve recovery of the Swainson's hawk by increasing the quality and quantity of its habitats. Limiting land use changes can help to retain foraging and nesting habitat. Because many agricultural practices are compatible with Swainson's hawk foraging, simply improving the timing of farming activities would further improve foraging habitat.
Strategies could be implemented collaboratively with organizations to improve existing preserves that support Swainson's hawk habitat. Cooperative agreements with land management agencies, conservation easements or landowner incentives will improve land management practices for the Swainson's hawk.

Restoration of habitats proposed in other ecological zones will also allow Swainson's hawk nesting and foraging habitats to develop elsewhere in the Central Valley.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Several organizations have plans that indirectly target the Swainson's hawk for recovery through habitat restoration.

- The Riparian Habitat Joint Venture includes 11 federal, State, and private organizations that signed a cooperative agreement to protect and enhance habitats for native land birds throughout California.

- The Putah Creek - South Fork Preserve, which works to increase fish and wildlife populations dependent on riparian and wetland habitats, including species of special concern, plans to restore 130 acres of riparian habitat.

- The Upper Sacramento River Fisheries and Riparian Habitat Management Plan (SB1086) also targets riparian habitat for restoration that will benefit the Swainson's hawk.

- Restoration and strategies should be coordinated with the Swainson's Hawk Technical Group, a group of agency and non-agency specialists dedicated to restoring the health of this species.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration of the Swainson's hawk population is integrally linked with restoration of riparian, grassland, and agricultural habitat in the Central Valley.

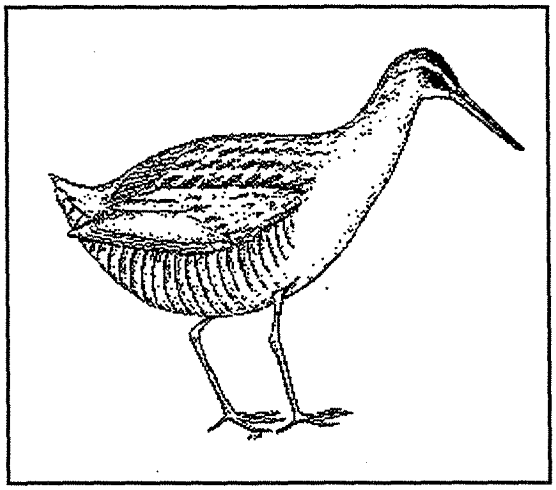
IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the Swainson's hawk is to assist in the recovery of this State-listed threatened species. Recovery of Swainson's hawk would contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

The general target is to increase the number of breeding pairs of Swainson's hawks in the Central Valley.

General programmatic actions that will contribute to reaching the targets include:

- protect existing and restoring additional suitable valley oak and other riparian habitats and grasslands;
- improve agricultural land management;
- reduce the effect of factors that can suppress breeding success;
- protect known nest sites from loss, degradation, or disturbance during the entire year;
- increase prey populations (e.g., rodents) necessary to support an expanding population;
- establish buffer zones that eliminate human disturbance during nesting; and
- create compatible land use management adjacent to important habitats.



INTRODUCTION

The clapper rail is a year-long resident in coastal wetlands and brackish areas around San Francisco Bay. Within the Central Valley, this species is found only in the Suisun Marsh/North San Francisco Bay Ecological Zone. The California clapper rail is associated with saline (saltwater) emergent wetlands. The population and distribution of this species have declined substantially, primarily as a result of reclamation of its tidal saltmarsh habitats. The loss of habitat and declining condition of the species' population have warranted its listing as endangered under the State and federal Endangered Species Acts.

Major factors that limit this resource's contribution to the health of the Delta are related to adverse effects of historical and current loss or degradation of tidal saltmarshes for agricultural, industrial, and urban uses, and excessive predation on nests and individuals by non-native predators.

RESOURCE DESCRIPTION

Habitat loss is largely a result of reclamation for agricultural, industrial, and urban uses and water management projects. Populations have also been limited due to loss or degradation of tidal saltmarshes for waterfowl hunting and management. The total area of these remaining habitats represents only a small percentage of their historic level. The California clapper rail breeds from February through August. The preferred habitat is saline tidal marshes but are known to use brackish marsh areas with alkali bulrush. It builds a platform nest concealed by a canopy of cordgrasses and pickleweed. It may also use cattails and bulrushes in fresh emergent wetland habitats although these area are not considered suitable foraging and breeding habitat. Adjacent upper wetland or upland habitat with aquatic vegetation are also important because they provide nesting and escape cover during high tides and floodwaters.

Significant loss of saline and brackish emergent wetland habitat and associated upland habitats and high marshes is the primary factor for the decline in this species' populations. These habitat losses have reduced populations sufficiently that predation by non-native species, such as the Norway rat, red fox, and feral cats; swamping of nests by boat wakes; and contaminants, such as selenium, are now also be substantial factors affecting the ability of the species to recover.

VISION

The vision for the California clapper rail is to assist in the recovery of this State- and federally listed endangered species to contribute to overall species richness and diversity. Achieving this vision will reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

Protecting existing and restoring additional suitable saline and brackish emergent wetlands and adjacent higher elevation habitats and reducing the effect of other factors that can suppress breeding success will be critical to the recovery of the California clapper rail. The Suisun Marsh and San Francisco Bay areas once comprised a mosaic of large contiguous blocks of tidal saline emergent wetland in association with adjacent upland habitats. Restoration of saline and brackish emergent wetland and associated upland habitats in the Suisun Marsh/North San Francisco Bay Ecological Zone will help the recovery of this species by increasing habitat area.

Upland cover could be improved by providing incentives to farmers to allow natural vegetation to reclaim portions of the upland habitat adjacent to tidal wetlands.

Clapper rail habitat utilization in Suisun Marsh and the Napa Marshes suggest that a natural network of small tidal creeks which begin high in the marsh and grade down into large tidal sloughs and bays are essential habitat components for successful breeding populations. Improved habitat would also include water quality levels and other components necessary to support isopods, arthropods, mollusks, and insects on which clapper rails forage. These components could be provided by developing and implementing a program to reduce the level of toxins that adversely affect clapper rail populations in the Bay-Delta. Clapper rail breeding success could be improved by reducing the adverse effects of boat wakes on nests during the February through August breeding period. Restoring high-quality clapper rail habitat would also reduce the adverse effects of predation by non-native species by creating habitat conditions that are more favorable for rails and less favorable for predators.

Improved habitat would also include water quality levels and other components necessary to support isopods, arthropods, mollusks, and insects on which clapper rails forage. These components could be provided by developing and implementing a program to reduce the level of toxins that adversely affect clapper rail populations in the Bay-Delta. Clapper rail breeding success could be improved by. Restoring high-quality clapper rail habitat would also reduce the adverse effects of predation by non-native species by creating habitat conditions that are more favorable for rails and less favorable for predators.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Wetland restoration and management programs that would improve habitat for the clapper rail include:

- the Agricultural Stabilization and Conservation Service's Wetland Reserve Program,
- the Wildlife Conservation Board's Inland Wetlands Conservation Program,
- protect remaining tidal slough habitats supporting pickleweed, cordgrass, bulrushes, and cattails,
- maintain adjacent higher elevation wetland and upland habitat to provide cover during high tides and floods,
- the Suisun Marsh Protection Plan, and
- ongoing management of State and federal wildlife refuges and private duck clubs.

Restoration efforts will be conducted in cooperation with agencies or organizations with responsibility or authority for restoring wetland and aquatic habitats, including:

- the California Department of Fish and Game,
- California Department of Water Resources,

- U.S. Fish and Wildlife Service (USFWS),
- U.S. Army Corps of Engineers, and
- the Delta Protection Commission.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Improvement of the population of clapper rail in the Bay is integrally linked with wetland and riparian habitat restoration, and water quality (contaminants) improvement.

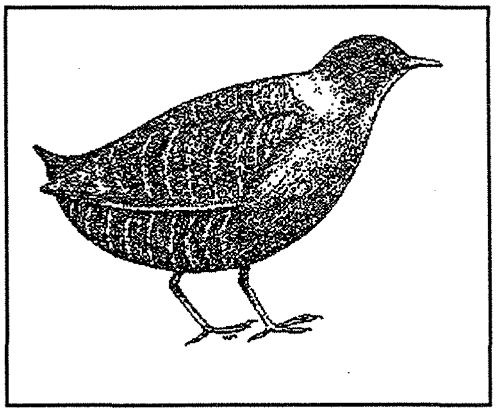
IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the clapper rail is to assist in the recovery of this State- and federally listed endangered species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

The general target it to increase the numbers of breeding pairs of clapper rails in the Bay-Delta. The USFWS is currently revising the recovery plan for the clapper rail, which will establish population recovery goals.

The following general programmatic actions will contribute to meeting the target for the California clapper rail:

- restore saline emergent wetland habitat in the Bay,
- protect remaining tidal slough habitats supporting pickleweed, cordgrass, bulrushes, and cattails, especially in areas adjacent to high marsh meadows characterized by pickleweed-saltgrass plant associations,
- improve water quality of Bay marshes,
- reduce the adverse effects of boat wakes on nests during the breeding period,
- develop and implement predator control programs,
- maintain adjacent higher elevation wetland and upland habitat to provide cover during high tides and floods, and
- improve upland cover by providing incentives to farmers to allow natural vegetation to reclaim portions of the upland habitat adjacent to tidal wetlands.



INTRODUCTION

The California black rail is a rarely seen, year-round resident of saline, brackish (somewhat salty), and fresh emergent wetlands and viable populations of the species are found only in the Suisun Marsh, San Francisco Bay, and the Delta. The California black rail is associated with tidal and nontidal emergent wetlands. The population and distribution of this species have declined substantially primarily as a result of reclamation of its wetland habitats. The loss of habitat and declining condition of the species' population have warranted its listing as threatened under the California Endangered Species Act. The major factor that limits this resource's contribution to the health of the Delta is related to the adverse effects of historical and current loss or degradation of salt-, brackish, and freshwater marshes.

RESOURCE DESCRIPTION

Historically, the black rail was a resident of coastal wetlands from Santa Barbara County to San Diego County. Much of the California black rail's marshland habitat in California has been destroyed or modified since the mid-1800s. This decline in marshland has reduced population densities of black rail throughout its range.

Important habitats for the species include tidal perennial and nontidal perennial aquatic, dead-end and open-ended sloughs, seasonal wetland and aquatic, saline and fresh emergent wetland, and midchannel islands and shoals. Many tidal habitats, including those that support pickleweed, bulrushes, and saltgrass, are critical types for this species that need to be protected and currently exist as only a small percentage of their historical extent. In addition, upper wetland or upland areas adjacent to these habitat areas provide nesting and escape cover during high tides and floods.

Black rail habitat is directly influenced by sediment supply from the upstream portion of the Delta and tidal influences from the Bay. As sediment is deposited in a tidal marsh, the elevation of the marsh changes. Eventually, the marsh may no longer be affected by tidal action or support tidal marsh plants which depend on the interaction of compatible tides and sediment supply regimes. Water quality in habitat areas must be sufficiently high to support the invertebrates and vegetation that sustain black rails. The condition most hazardous to the black rail's existence in salt marshes is the elevated water level associated with the highest tides and high outflow conditions. High water destroys nests and forces rails to leave the marsh temporarily in search of sufficient cover in uplands. Black rails use corridors between wetland and upland habitats to seek cover during high tides. However, these corridors have been fragmented by the extensive system of Delta levees, which are often devoid of vegetation. This lack of sufficient cover subjects black rails to predation, frequently by non-native species. These habitats continue to be threatened by sedimentation, water diversions, recreational activities, and land use practices. Insufficient quantity and quality of emergent wetland habitat is the primary factor limiting recovery of the species' population in the estuary. Other factors that can also adversely affect the black rail include disturbance during its breeding period, contaminants, and excessive predation by non-native species.

VISION

The vision for the California black rail is to assist in the recovery of this State-listed threatened species to contribute to overall species richness and diversity. Achieving this vision will reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

Restoring suitable fresh and saline emergent wetlands and tidal sloughs in the Bay-Delta and adjacent higher elevation habitats is critical to the recovery of the species in the estuary. These restored habitats would provide refuge for the California black rail during high-water periods. Although the black rail's range extends into other ecological zones, the primary focus for habitat restoration will be in the Sacramento-San Joaquin Delta Ecological Zone and the Suisun Marshland Ecological Unit in the Suisun Marsh/North San Francisco Bay Ecological Zone. Efforts outside the Delta and Suisun Marsh to restore natural tidal action to aquatic and wetland habitats within the Suisun Marsh/North San Francisco Bay Ecological Zone would also benefit the species.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Many programs designed to benefit broader groups of fish and wildlife that use or depend on wetlands, sloughs, or adjacent aquatic systems in the Bay-Delta also benefit the California black rail. Some of these are operated by the following organizations:

- Bay Area Wetlands Planning Group,
- California Coastal Conservancy,
- Delta Native Fishes Recovery Team,
- San Francisco Bay National Wildlife Refuge,
- the U.S. Fish and Wildlife Service San Francisco Bay Program, and
- the Tidal Wetlands Recovery Plan Ecosystem Wetland Goals Project.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration and recovery of the California black rail population of the Bay-Delta is integrally linked with wetland and riparian habitat restoration, and water quality (contaminants) improvement.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the California black rail is to assist in the recovery of this State-listed threatened species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

The general target is to increase the number of breeding pairs of Clapper rail in the Bay-Delta.

General programmatic actions to achieve the target for the California black rail include:

- restore the natural tidal action of aquatic habitats;

- preserve the remaining populations of black rail, tidal slough habitats that support pickleweed, bulrushes, and saltgrass;

- enhance and restore connectivity between tidal sloughs and adjacent upland refugial habitats;

- improve the connection between wetland and upland habitat areas to reduce predation;

- implement management programs for small water diversions, disturbance, land use changes, and contaminants would improve habitat, reproductive potential, and recruitment for black rails;

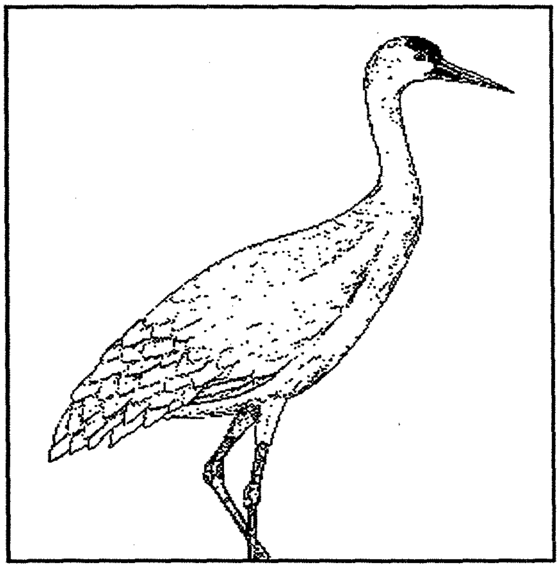
- protect tidal sloughs and wetlands from adverse land uses;

- protect nearby unoccupied suitable habitat areas would help ensure natural expansion area is available;

- protect of existing suitable habitats by implementing conservation easement purchasing from willing landowners, or establishing incentive programs to maintain suitable habitat;

- develop and implement alternatives to land management practices on public lands that continue to degrade the quality or inhibit the recovery of black rail habitats; and

- restore, protect, and improve emergent wetlands, tidal sloughs, and adjacent uplands.



INTRODUCTION

This subspecies of the sandhill crane primarily winters in the Delta and forages and roosts in agricultural fields and pastures. Because the winter range of the greater sandhill crane overlaps the winter range of other sandhill crane subspecies, all subspecies are considered important resources. The greater sandhill crane population has declined primarily as a result of loss of suitable wetland nesting habitats. The loss of habitat and declining condition of the subspecies' population have warranted its listing as threatened under the California Endangered Species Act. Major factors that limit this resource's contribution to the health of the Bay-Delta are related to adverse effects of conversion of grassland and wetland habitats for agricultural, industrial, and urban uses.

RESOURCE DESCRIPTION

The greater sandhill crane is an important part of the biological integrity and health of the Bay-Delta and Sacramento-San Joaquin Valley ecosystems. The greater sandhill crane is found throughout most of the Central Valley in winter and nests in northeastern California and Oregon.
Habitats used by the sandhill crane include seasonal and fresh emergent wetlands, grasslands, and agricultural lands. Large wintering populations of greater and lesser sandhill cranes congregate in the Sacramento and San Joaquin Valleys. Generally, crane wintering habitat consists of shallowly flooded grasslands that are used as loafing and roosting sites and nearby agricultural areas that provide food sources include rice, sorghum, barley, and corn. In the Delta, in adequate roost sites, relatively free from disturbance and quality and quantity of forage, are potential limiting factors on the wintering population.

The State-listed greater sandhill crane is a fully protected species because the small remaining population depends on habitat that is threatened with loss or degradation. The conversion of grasslands, wetlands, and agricultural land to urban development is an ongoing process that is not likely to be reversed. The sandhill crane now depends primarily on artificially created areas where natural wetland and grassland habitats have been eliminated. Disturbance associated with human activities, illegal harvest, and predation have also affected the overall health of the crane population, although less severely than the loss and degradation of its habitats.

VISION

The vision for the greater sandhill crane is to assist in the recovery of this State-listed threatened species in the Bay-Delta. Recovery of the greater sandhill cane would contribute to overall species richness and diversity. Achieving this vision will reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

Maintenance of healthy populations of other sandhill crane subspecies will also improve by providing sufficient wintering habitat in the Bay-Delta. Habitat restoration these in the Sacramento-San Joaquin Delta Ecological Zone will help maintain healthy populations.

The greater sandhill crane will benefit from restoration of shallowly flooded wetlands. Implementing existing crane recovery and waterfowl management plans will also help achieve this vision. Such strategies could be implemented through collaborative work with organizations to maintain and improve existing preserves, cooperative agreements with land management agencies, or conservation easements or purchase from willing sellers.

Restoration of ecosystem processes and habitats in other ecological zones will also allow seasonal and fresh emergent wetlands and grasslands to develop that will provide habitat for wintering sandhill cranes elsewhere in the Central Valley.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Restoration of sandhill cranes in the Central Valley is conducted by the following programs:

- A Pacific Flyway Management Plan for the Central Valley population of greater sandhill cranes to recover the population has been developed and is being implemented by the U.S. Fish and Wildlife Service and the California and Oregon Departments of Fish and Game.

- The Central Valley Habitat Joint Venture Implementation Plan contains goals to protect and restore Central Valley aquatic and upland habitats that are needed for waterfowl. This plan provides indirect benefits for the greater sandhill crane and other species that use these wetland and upland habitats.

- California Department of Fish and Game and The Nature Conservancy are working to protect and restore crane habitat in the area of the Woodbridge Ecological Reserve and the Cosumnes River Preserve.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration and recovery of the greater sandhill crane population of the Central Valley is integrally linked with wetland and riparian habitat restoration, and agricultural habitat improvement.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the greater sandhill crane is to assist in the recovery of this State-listed threatened species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

General targets for greater sandhill crane are to:

- increase the number of greater sandhill cranes in the Central Valley population, and

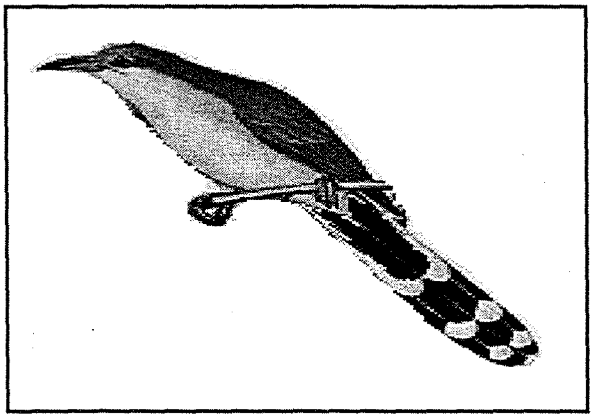
- increase the distribution of greater sandhill crane in the Central Valley.

General programmatic actions to help reach the targets include:

- protect existing habitats and restore additional suitable seasonal and fresh emergent wetlands and grasslands, and

- improve agricultural land management.

WESTERN YELLOW-BILLED CUCKOO



INTRODUCTION

The western yellow-billed cuckoo is associated with mixed riparian and cottonwood forests. This species has been eliminated from the Bay-Delta. Elsewhere, the population and range of this species have declined primarily as a result of the loss or degradation of extensive, mature and successional riparian cottonwood forests. The loss of habitat and declining condition of the species' population have warranted its listing as endangered under the California Endangered Species Act.

Major factors that limit this resource's contribution to the health of the Delta are related to adverse effects of flood control and bank protection projects, which resulted in the direct loss of riparian forests and reduced or eliminated the processes that create and maintain floodplains that support riparian forests, and reclamation of riparian forests for agricultural, industrial, and urban uses.

RESOURCE DESCRIPTION

Historically, the yellow-billed cuckoo commonly occurred from the Mexican border along the coast belt through the San Francisco Bay region as far as Sebastopol, Sonoma County, and through the Sacramento and San Joaquin Valleys. Yellow-billed cuckoos inhabit extensive deciduous riparian thickets or forests with dense, low-level or understory foliage that abut rivers, backwaters, or seeps. The cuckoo, is limited to some reaches of the Sacramento River, Sanborn Slough in the Butte Sink, and the Feather River. The population of this species is critically low.

Dense, large patches of willow-cottonwood riparian habitat are the preferred nesting habitat for this neotropical migrant. This habitat was once much more common, particularly along the Sacramento and San Joaquin Rivers; however, conversion of land to agriculture, urbanization, and flood control projects have caused the loss of habitat. Other stressors that continue to adversely affect the species are loss of habitat as a result of bank protection projects, mortality associated with non-native nest parasites and predators, and inadvertent drift of some types of herbicides and pesticides into habitat areas.

VISION

The vision for the western yellow-billed cuckoo is to assist in the recovery of this State-listed endangered species. Recovery of this species would contribute to overall species richness and diversity. Achieving this vision will reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

Protection and restoration of existing and suitable mature riparian forest will be critical to the recovery of the yellow-billed cuckoo. Restoration of riparian habitats in the Sacramento-San Joaquin Delta, Sacramento River, Cottonwood Creek, Colusa Basin, Feather River/Sutter Basin, and American River Basin Ecological Zones will help to recover this species by increasing the quality and quantity of its habitat.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

No program is specifically charged with restoring yellow-billed cuckoo populations. Restoration efforts sponsored by the Upper Sacramento Fish and Riparian Habitat Advisory Council (SB1086) have the potential for benefitting the species. The purpose of riparian habitat planning through the SB1086 program is to preserve remaining riparian habitat and reestablish a continuous riparian ecosystem along the Sacramento River.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration and recovery of the yellow-billed cuckoo population of the Central Valley is integrally linked with wetland and riparian habitat restoration, and agricultural habitat improvement.

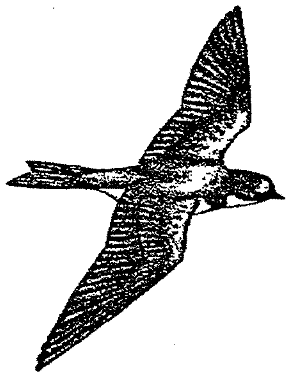
IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the western yellow-billed cuckoo is to assist in the recovery of this State-listed endangered species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

The general target is to increase the population of yellow-billed cuckoo in the Central Valley.

The general programmatic action which will assist in reaching the target is:

- improve and restore riparian forest habitat in the Central Valley.



Bank Swallow
Threatened (State)

INTRODUCTION

The bank swallow is associated with riparian and riverine habitats and nests in vertical cliff and bank faces eroded by rivers. The population and range of this species have declined primarily as a result of the loss or degradation of ecosystem processes that maintain suitable nesting substrates along streams and rivers. The loss of habitat and declining condition of the species' population have warranted its listing as threatened under the California Endangered Species Act. The major factor that limits this resource's contribution to the health of the Delta is related to the adverse effects of levees and bank-protection structures on river and stream channel migration. These structures inhibit or prevent the channels' ability to erode its banks and form the nesting cliffs and banks required by the species.

RESOURCE DESCRIPTION

Once an abundant lowland species in California, the bank swallow is now limited to breeding in a small part of its former range. The bank swallow is found in only a small number of ecological units within the Central Valley's ecological zones that are adjacent to major rivers and their tributaries. The species is not known to occur in the Sacramento-San Joaquin Delta or the Suisun Marsh/North San Francisco Bay Ecological Zones. Nesting colonies are found along the Sacramento River from mile 143 to 243, with 40-60 colonies remaining along the upper Sacramento River and and approximately 10-20 colonies on the Feather River. A total of 5-10 colonies are located above and below miles 143 on the Sacramento River. Other small colonies are found along other waterways, including: the American River, Thomes Creek, Cache Creek, and the Cosumnes River.

Bank swallows breed in vertical banks or cliffs that are created when streams and rivers erode their banks. Friable soils are an important habitat requirement. Their population is estimated to have been reduced by 50% since 1900. Only a few colonies remain within the State as a result of stream channelization, bank protection, and flood control projects, which have reduced the availability of breeding sites (i.e., cliffs) by constraining rivers from eroding their banks. As much as 75% of the current breeding population in California concentrates along the banks of the Central Valley's streams; 70-80% of remaining breeding habitat is found along a small stretch of the Sacramento River.

The decline of the bank swallow can be attributed primarily to human activities that have changed the ecosystem processes that create and sustain its bank and bluff nesting habitat. Stream meander migration is necessary to maintain, enhance, and create the fine-textured or sandy-type vertical banks or cliffs in which bank swallows dig their nesting holes. Levees and riprapped banks along streams and rivers have impeded the creation of nesting cliffs by preventing channels from following the natural process of erosion, deposition, and meandering. Currently proposed projects for confining channels within the species' nesting range represent the largest threat to maintaining existing bank swallow colonies. The general deterioration or loss of adjacent floodplain habitats (e.g., shaded riverine aquatic, riparian corridors and forests, and open grasslands) has also, although to a lesser degree, contributed to the species' decline.

VISION

The vision for the bank swallow is to assist in the recovery of this State-listed threatened species. Recovery of the bank swallow would contribute to overall species richness and diversity. Achieving this vision will reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

Protecting existing nesting colonies from activities that could result in their loss or degradation and restoring ecological process of confined channel migration will be critical to the recovery of the bank swallow. The Ecosystem Restoration Program Plan's proposed restoration of stream meander and riparian habitat in the Sacramento River and Butte Basin Ecological Zones will help to protect the remaining nesting colonies along the Sacramento and Feather Rivers. Protecting the remaining nesting colonies is an essential requirement to preventing the bank swallow population from declining to a point where restoration efforts may offer little help to the species.

Recent studies have shown that most nesting colonies are adjacent to open grasslands. Other colonies live in agricultural lands and riparian and oak forests. Restoring these habitats while protecting and restoring streamside banks and levees would also help maintain or increase existing bank swallow populations.

Restoring Sacramento River meander belts and other confined streams and rivers is an approach that would restore, on a large scale, the processes that create nesting banks. Partially restoring the processes that create nesting sites would be feasible in some areas by modifying flood control and bank stabilization practices to allow channels to migrate and cut banks.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Other programs linked to restoring riparian systems and bank swallow habitat include:

- the Upper Sacramento River Fisheries and Riparian Habitat Advisory Council (SB 1086),
- the Central Valley Improvement Act,
- Anadromous Fish Restoration Program,
- Cosumnes River Preserve,
- Delta Native Fishes Recovery Team,
- Department of Fish and Game Central Valley Salmon and Steelhead Management and Restoration Program,
- Riparian Habitat Joint Venture, and
- California Department of Fish and Game's recovery plan for the bank swallow.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration of the bank swallow population and its habitat will be integrally linked to restoration of natural stream meander corridors in the rivers of the Central Valley.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the bank swallow is to assist in the recovery of this State-listed threatened species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

The general target is to increase the number of bank swallow pair in the Central Valley.

General programmatic actions which will contribute to reaching the target include:

- protect existing nesting colonies along the Sacramento River, Feather River and their tributaries,
- restore natural river meander process, and
- increase and link potential nesting habitat.

INTRODUCTION

Suisun song sparrows live only in and around the Suisun Marsh and Bay. The Suisun song sparrow is associated with saline emergent wetlands. The population and distribution of this species have declined substantially primarily as a result of reclamation of tidal saltmarshes. The loss of habitat and declining condition of this species' population have warranted its inclusion as a species of special concern. Major factors that limit this resource's contribution to the health of the Delta are related to adverse effects of historical and current loss or degradation of tidal saltmarshes for agricultural, industrial, and urban uses and excessive predation on nests and individuals by non-native predators.

RESOURCE DESCRIPTION

Historically, much of the Suisun Marsh was a brackish tidal marsh. The Suisun song sparrow inhabited areas with suitable brackish marsh vegetation. The total area of historical tidal marsh habitat is estimated to have been about 66,600-73,700 acres. Between 70,000 and 77,000 pairs of Suisun song sparrows are estimated to have used the available marsh habitat annually. Recent estimates indicate that fewer than 6,000 pairs remain in 13 isolated populations, representing 8% of the species' former abundance. The remaining 13 populations number from about 1,300 pairs to about 20 pairs.

Since artificial levees were constructed beginning in the late 1800s, the managed marsh areas on the nontidal side of the levees are flooded seasonally and then drained or allowed to dry. These areas are consistently avoided by Suisun song sparrows. The birds require appropriate vegetation for nesting sites, song perches, and foraging cover. The vegetation must also produce seeds or harbor invertebrates that the birds pick up from the surface of mudflats. Each sparrow's territory must contain permanent water or moisture in the form of tidal ebb and flow. Typically, each territory contains at least one patch of tall, hard-stemmed bulrush that stands above the surrounding vegetation and is used as a singing perch. The birds apparently need these high song perches to establish territory, and the absence of song perches may be a limiting factor in the distribution of pairs.

The Suisun song sparrow is physiologically and behaviorally adapted to this area's naturally occurring brackish (somewhat salty) tidal conditions. It can drink brackish water and breeds earlier than upland subspecies. Early breeding avoids nest flooding during the highest spring tides. The Suisun song sparrow forages for invertebrates and seeds directly on the surface of mudflats.

The primary threat to the continued existence of the Suisun song sparrow is the severe fragmentation of brackish tidal marsh habitat in and around Suisun Marsh. The once-vast marsh has been reduced to small areas that are separated by barriers or connected only by narrow strips of vegetation along the banks of tidal sloughs. Interbreeding between populations in these areas is rare. As the southern shore of Suisun Marsh in Contra Costa County becomes increasingly industrialized and developed, habitat will continue to be degraded and, ultimately, the southern population may no longer be viable. Egg and nestling mortality is about 50% in the first 3 weeks after eggs are laid. The primary causes of this mortality are predation on eggs and nestlings by the introduced Norway rat, predation on nestlings by feral house cats, and flooding of nests during periods of high tides. Maintenance of levees, dikes, and other structures during the breeding period may also create sufficient disturbance to cause nesting failure. Levees constructed in the sparrow's habitat are high enough above the surrounding marsh to allow the growth of upland plants that require fresh water.

Although Suisun song sparrow territories may include these areas, the species avoids centering its territory in this type of vegetation.

Long-term changes in the salinity gradient of the Bay-Delta may also have an effect on the species' distribution and abundance. The normal brackish condition of Suisun Marsh is directly attributable to the amount of freshwater outflow it receives from the Delta. This fresh water mixes with saltwater transported on incoming tides through Carquinez Strait. The amount of freshwater outflow has been reduced since historical times during water-years that are now considered normal. Suisun song sparrows can withstand short-term alterations in brackish conditions because they can subsist on pure saltwater for several days. The vegetation they occupy in the brackish marsh is similarly adapted. If the water regime changes drastically or for long periods, however, a large-scale change in habitat could result. If salinity decreases, the Suisun song sparrow could face lowered reproductive rates, increased competition, and loss of genetic integrity as a result of breeding with invading upland subspecies that consume fresh water. If the water becomes too salty, saltwater marsh vegetation could displace brackish vegetation; saltwater marsh is not suitable habitat for the species, which is not adapted to consume saltwater for extended periods.

VISION

The vision for the Suisun song sparrow is to increase the habitat for this species of special concern in Suisun Marsh and the western Delta.

Protecting and restoring existing and additional suitable tidal saline and fresh emergent wetlands (including brackish marshes) and reducing breeding stressors will be critical to the recovery of the Suisun song sparrow.

Restoration of tidal emergent wetlands in the Suisun Marsh/North San Francisco Bay Ecological Zone will help to recover this species by increasing its habitat area. Restoring associated higher elevation uplands would provide escape cover during high tides and flooding. Restoring these habitats would allow the population to increase at existing protected habitat areas and would ensure long-term survival. The restoration of high-quality sparrow habitat would also reduce the adverse effects of predation by non-native species by creating habitat conditions that are more favorable for sparrows and less favorable for predators.

The potential adverse effects of disturbance on breeding success could be reduced by encouraging agencies, organizations, and private landowners, through cooperative agreements and incentive programs, to conduct infrastructure maintenance activities in occupied habitat areas so that tidal brackish marsh vegetation is disturbed as little as possible and adults are not disturbed during the breeding season. The possibility of managing breeding of the species to increase its reproductive success should be investigated (e.g., transferring eggs and/or young between nearby isolated populations to increase genetic interchange between populations). If the species is susceptible to responding to such manipulations, the period for its recovery would be reduced.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Programs and projects designed to protect, restore, and enhance the Suisun Marsh/North San Francisco Bay Ecological Zone to provide direct or incidental benefits to the Suisun song sparrow include:

- San Francisco Estuary Project,
- Bay Area Wetlands Planning Group,
- Cache Creek Corridor Restoration Plan,
- California Wetland Riparian Geographic Information System Project,

- Governor's California Wetland Conservation Policy,
- Tidal Wetlands Species Recovery Plan,
- Wetlands Reserve Program,
- Inland Wetlands Conservation Program,
- Montezuma Wetlands Project, and
- National Estuarine Reserve Research System.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration of the Suisun Song Sparrow is integrally linked with restoring tidal permanent emergent wetlands in Suisun Bay and Marsh and the western Delta. Restoration of adjacent tidal perennial aquatic habitat, particularly mudflats, is also important.

IMPLEMENTATION OBJECTIVE, TARGET, AND PROGRAMMATIC ACTIONS

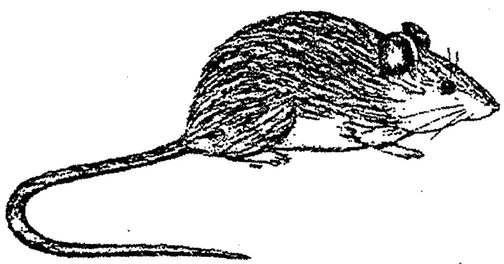
The implementation objective for the Suisun song sparrow is to increase habitat for this species of special concern in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

The following general targets will assist in meeting the implementation objective:

- Increase the total number of pairs.
- Increase the number of pairs in each of the 13 isolated populations.
- Increase the number of populations.
- Reduce the extent of isolation among the populations.

The following general programmatic actions will assist in meeting the targets:

- Increase the amount of tidal brackish water marshes in Suisun Bay and Marsh and in the western Delta.
- Decrease the extent of isolation of remaining tidal marshes in Suisun Bay and Marsh and the western Delta.
- Increase the amount of grassland habitat adjacent to tidal marshes in Suisun Bay and Marsh and the western Delta.
- Within existing and restored marshes ensure presence of tall, hard-stemmed bulrush stands.
- Increase the area of tidal mudflats in close proximity to existing and restored marshes.



Salt Marsh Harvest Mouse
Endangered (Federal)
Endangered (State)

INTRODUCTION

The salt marsh harvest mouse is associated with saline emergent wetlands. The population and distribution of this species have declined substantially, primarily as a result of reclamation of tidal salt marshes for agriculture, salt production, and urban development. The loss of habitat and declining condition of this species' population have warranted its listing as endangered under the State and federal Endangered Species Acts. The major factors that limit this resource's contribution to the health of the Delta are related to the adverse effects of historical and current loss or degradation of saline tidal wetlands that support the dense stands of pickleweed on which the salt marsh harvest mouse is dependent.

RESOURCE DESCRIPTION

The salt marsh harvest mouse occurs only in saline emergent wetlands associated with San Francisco Bay and its tributaries. Historically, these areas supported extensive tidal wetlands, which sustained dense stands of pickleweed. These plants, in turn, supported the salt marsh harvest mouse.

With the gradual development of the Suisun Marsh and San Francisco Bay areas came the construction of dikes and levees for flood control and protection of lands reclaimed for uses such as for salt ponds and agriculture. These reclaimed areas supported livestock grazing and, in the Suisun Marsh, small grain crops and asparagus. The vegetation growing beyond the limits of high tide supported grazing, and settlers found that if they diked those areas, wetland plants would eventually recede and give way to upland plants favored by livestock. As more and more settlers arrived, development resulted in the loss of large areas of habitat and severe fragmentation of the habitat that remained. Barriers, such as a road or path no more than 10 feet across, isolated the mouse in fragmented habitats because it would not use or travel across areas lacking vegetation. Upland areas consisting of grasslands or salt-tolerant plants that offered refuge during extreme high tides and high outflow periods were adjacent to the saline emergent wetlands. Development altered the landscape and geomorphology in many of these areas, which contributed to the loss of habitat.

Saline emergent wetlands with pickleweed occur only within the Suisun Marsh/North San Francisco Bay Ecological Zone of the Ecosystem Restoration Program Plan (ERPP) area. The elimination of much of the salt marsh harvest mouse's habitat is the primary cause of the species' decline. Other factors or "stressors" that have contributed to the decline or potentially could inhibit the recovery of the species include human activities that disturb the species and predation by non-native species. Grazing; water management practices; land use practices; contaminants; and human-made structures, such as dikes and levees, continue to degrade the quality of remaining habitat areas.

VISION

The vision for the salt marsh harvest mouse is to assist in the recovery of this State- and federally listed endangered species through restoring salt marsh in San Pablo and Suisun Bays and adjacent marshes. Existing occupied and unoccupied suitable habitat areas will be protected. Saline emergent wetlands will be restored. Stressors to the population and habitat will be reduced. new populations will be introduced into unoccupied habitat areas.

Protecting existing suitable habitat areas from potential activities that could adversely affect the harvest mouse could be achieved through cooperative agreements with land management agencies, conservation easements, or purchase from willing sellers. Restoration of adjacent upland habitat will help to recover this species by increasing habitat area. Uplands provide the mouse with refuge from flooding.

Reducing factors that contribute to degradation of saline emergent wetland communities would promote natural restoration and maintenance. Increasing the quantity and quality of salt marsh harvest mouse habitat and reducing the adverse effects of stressors would establish conditions necessary to maintain existing populations and allow them to naturally recover. However, introducing the mouse into unoccupied habitat areas within its historic range would speed the recovery of the species by establishing new populations before the species would be expected to naturally expand into these or restored habitat areas.

Many programs are underway to restore the Bay-Delta salt marshes. Successful restoration program implementation will increase the chances of salt marsh harvest mouse recovery. Current land management practices need to be examined and redefined to restore, enhance, and promote salt marsh harvest mouse habitat. Salt marsh harvest mouse management strategies should focus on:

- managing known critical mouse habitat areas;
- providing additional research to identify other factors limiting the population and determine corrective measures; and
- addressing the needs of waterfowl and other migratory birds that also use saline emergent wetlands.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Existing restoration programs that would benefit the salt marsh harvest mouse include:

- Suisun Marsh Recovery Plan,
- San Francisco Bay Joint Venture,
- Bay Area Wetlands Planning Group,
- California Coastal Conservancy,
- Delta Native Fishes Recovery Plan,
- California Department of Fish and Game Delta/Bay Enhanced Enforcement Program,
- Grizzly Island Wildlife Area,
- National Estuarine Reserve Research System,
- North Bay Wetlands Protection Program,
- San Francisco Bay National Wildlife Refuge,
- Tidal Wetlands Species Recovery Plan, and
- San Francisco Bay Wetlands Ecosystem Goals Project.

Targets and actions will be coordinated through these programs.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration of salt marsh harvest mouse is integrally linked with restoration of saline emergent wetlands and adjacent grasslands adjacent to San Pablo and Suisun Bays.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

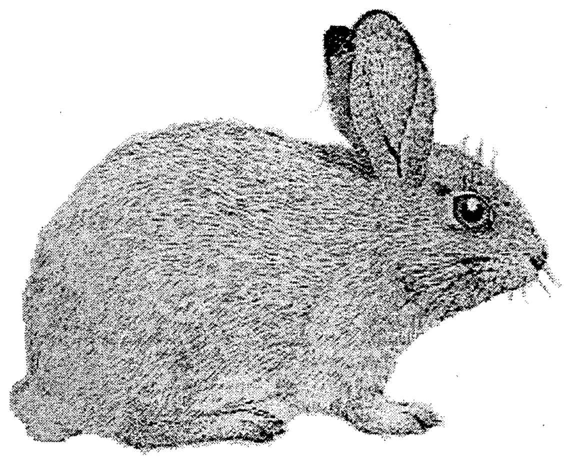
The implementation objective for the salt marsh harvest mouse is to assist in the recovery of this State- and federally listed endangered species in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

The following general targets will assist in meeting the implementation objective:

- Increase the number of salt marsh harvest mice in San Pablo and Suisun Bay marshes.
- Reduce the extent of isolation among the mouse populations.

The following general programmatic actions will assist in meeting the targets:

- Increase the area of salt marsh adjacent to San Pablo and Suisun Bays.
- Decrease the extent of isolation among remaining salt marshes.
- Increase the amount of adjacent grasslands to the marshes.
- Reduce the degree of stressors including water management and land use practices on existing and restored marshes and adjoining upland habitats.



INTRODUCTION

The riparian brush rabbit is associated with riparian habitats of the Central Valley floodplain. It has been eliminated from the Delta from loss of riparian habitat. Elsewhere, the population and distribution of this species have declined substantially, primarily as a result of the loss or degradation of its habitat. The loss of habitat and declining populations have warranted its listing as endangered under the California Endangered Species Act.

The major factor that limits this resource's contribution to the health of the Delta is related to adverse effects of the historical loss and degradation of the mature riparian forests, on which the riparian brush rabbit depends, in the Delta and San Joaquin River floodplain.

RESOURCE DESCRIPTION

The remaining population of riparian brush rabbit is restricted to remnant San Joaquin Valley riparian forests with dense brushy understory. Unlike other rabbits, the riparian brush rabbit occupies riparian forests that have an ample brushy understory within natural floodplains. These floodplain riparian forests must be attached to suitable upland areas for cover and retreat from annual floods. Historically, this species' habitat was throughout the floodplain on the valley floor in northern San Joaquin Valley, including the Delta, but the original forest and floodplain have been reclaimed, cleared, altered, and degraded.

The remnant population of riparian brush rabbit is now restricted to 198 acres of remaining native riparian forest along the Stanislaus River in Caswell Memorial State Park in southern San Joaquin County in the East San Joaquin Basin Ecological Zone. It is considered the most sensitive mammal in California because of its susceptibility to floods, fire, disease, predation, disturbance, and flood control activities. The large-scale loss of riparian forest has resulted in over a 99% decline in the riparian brush rabbit population from historical levels. A population census of the conducted during January 1993, found that the population size ranged from about 210 to 310 individuals. Subsequent surveys following the January 1997 flood indicate that this species by be close to extinction. No brush rabbits were trapped in 22 nights of trapping between April 21 and May 30, 1997.

Overall, the decline of the riparian brush rabbit was caused by the destruction, fragmentation, and degradation of the San Joaquin Valley native riparian forest habitat. Less than 6% of the original habitat remains. Remaining suitable habitat is so severely fragmented that the rabbit has no means of naturally dispersing to other areas and establishing additional populations. Because the remaining riparian brush rabbit population occurs within one small area, any of the following events threaten the remaining population:

- Caswell Memorial State Park is subject to periodic flooding that often inundates the entire area. Without adequate cover on adjacent upland areas, the rabbits become easy targets for both native and non-native predators.

- The normal buildup of downed logs, dried vegetation, and ground litter in the riparian forest increases the potential severity of wildfires. Although this type of habitat is preferred and typically occupied by the riparian brush rabbit, any wildfire occurring within the remaining habitat could cause direct mortality as well as massive habitat destruction.

- Human activities have modified the habitat. The modified habitat has "selected" against the riparian brush rabbit and for the desert cottontail. The desert cottontail presents two threats: one from competition and the other from diseases common to rabbits and carried by the species. These diseases are typically contagious and fatal; any disease becomes epidemic in this small and restricted population of rabbits.

VISION

The vision for the riparian brush rabbit is to assist in the recovery of this State-listed endangered species in the Bay-Delta through improvements in riparian habitat and reintroduction to its former habitat.

Restoring suitable mature riparian forest, protecting and expanding the existing population, and establishing new populations will be critical to the recovery of the riparian brush rabbit. Restoration of riparian habitats in the South Delta Ecological Unit of the Sacramento-San Joaquin Delta Ecological Zone and the East San Joaquin Basin Ecological Zone and adjacent upland plant communities will help the recovery of this species by increasing habitat area and providing refuge from flooding. Mature riparian forests with a brushy understory and adjacent upland habitat with sufficient cover during flooding would be suitable restored habitat. A healthy, brushy understory would contain:

- wild rose,
- blackberries,
- elderberries,
- wild grape,
- a buildup of downed logs,
- dried vegetation, and
- ground litter.

Restoring riparian habitat in the East San Joaquin Basin Ecological Zone to expand the area of suitable riparian brush rabbit habitat adjacent to occupied habitat along the Stanislaus River will help to protect and allow the existing population of brush rabbits to expand. Establishing additional populations within the riparian brush rabbit's historical range in the Sacramento-San Joaquin Delta Ecological Zone would help to avoid potential species extinction. To ensure the survival of introduced populations, newly occupied habitat areas should be suitable only for the riparian brush rabbit. That would reduce the likelihood of disease transmission from the desert cottontail. Hunting regulations should be modified to preclude hunting of rabbits and hares in and near reintroduction sites to limit the harvest of riparian brush rabbits until the species has recovered.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

A draft San Joaquin Recovery Plan has been developed which contains specific measures for the riparian brush rabbit. Resources agencies have identified Christman Island, part of the San Joaquin River National Wildlife Refuge, as possessing the greatest potential for providing habitat needed by the riparian brush rabbit. The agencies also agreed to continue work to identify one or more other sites on public property along the San Joaquin River in Merced County for restoration and reestablishment of a third population of the riparian brush rabbit. The California Department of Fish and Game and the U. S. Fish and Wildlife Service should continue the interagency coordination and commitment necessary to halt the further loss and deterioration of habitat and begin restoration and preservation of suitable habitat deemed essential to maintaining the subspecies in perpetuity.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration and protection of riparian brush rabbit is integrally linked with restoration of riparian forests and adjacent grasslands and reduction in wildfires and human disturbance in the northern San Joaquin Valley and the Delta.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

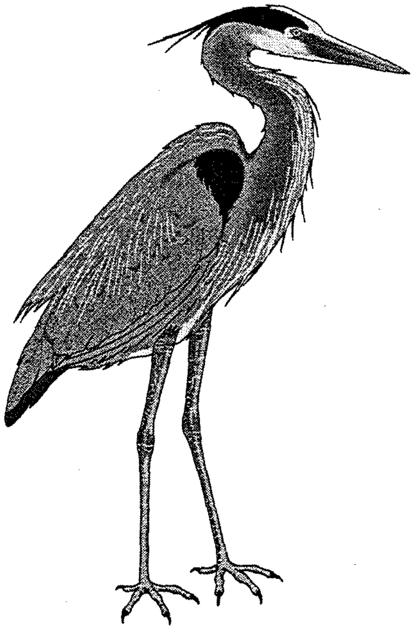
The implementation objective for the riparian brush rabbit is to assist in the recovery of this State-listed endangered species in the Bay-Delta in order to contribute to overall species richness and diversity and reduce conflict between the need for its protection and other beneficial uses of land and water in the Bay-Delta.

The following general targets will assist in meeting the implementation objective:

- Increase abundance in remaining population.
- Increase the number of rabbit populations.
- Increase the health of rabbits in the populations.

The following general programmatic actions will assist in meeting the targets:

- Expand the amount of riparian forest in the northern San Joaquin Valley and the Delta.
- Increase the amounts of specific habitat features needed by rabbits in riparian forests where the existing population occurs or where introduced.
- Expand the amount of upland habitat adjacent to riparian habitat where the existing populations occurs or to where new populations will be introduced.
- Manage existing and new habitats to reduce potential threat of wildfire and human disturbance including hunting.
- Control predators and non-native competitors where populations exist or will be introduced.



INTRODUCTION

Over a million shorebirds and wading birds annually migrate through, winter, or breed in the Bay-Delta. Representative species of the shorebird and wading bird guild include the great blue heron, great egret, western sandpiper, and long-billed dowitcher. These species are a significant component of the ecosystem, are of high interest to recreational bird watchers, and contribute to California's economy through sales of equipment and other bird-watching-related expenditures. There have been substantial losses of historic habitat used by these species and available information suggests that population levels of many of these species are declining. Major factors that limit this resource's contribution to the health of the Delta are related to adverse effects of conversion of native habitats for agricultural, industrial, and urban uses and land and water management practices that degrade habitats used by these species.

RESOURCE DESCRIPTION

Some shorebird and wading bird species are winter migrants limited to shallow water areas and shorelines. Others are statewide, year-round residents. Shorebirds and wading birds are dependent on many different habitats, although each species may be dependent on only one or a few habitats. These habitats include perennial aquatic, tidal slough, seasonal and emergent wetland, midchannel island and shoal, riparian, and agricultural.

Shorebirds and wading birds are present throughout the Central Valley. Herons and egrets are common year-round residents that breed and winter throughout the study area. Most shorebirds are only winter residents, with a small number remaining to breed. Wetland habitat conversion has eliminated 95% of the historic wetland habitat, resulting in smaller, detached patches of suitable habitat for nesting and foraging. Riparian habitats suitable for use by colonial-nesting species, such as egrets, have been lost or fragmented and are subject to increased disturbance during the nesting period.

VISION

The vision for the shorebird and wading bird guild is to maintain healthy populations of shorebirds and wading birds through habitat protection and restoration and reduction in stressors

Protecting existing and restoring additional suitable perennial aquatic, tidal slough, seasonal and emergent wetland, midchannel island and shoal, and riparian habitats and improving management of agricultural lands and reducing the effect of factors that can suppress breeding success will be critical to maintaining healthy shorebird and wading bird populations in the Bay-Delta.

Restoration of these habitats in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones will help to maintain healthy populations by increasing the quality and quantity of habitats used by these species.

Shorebirds and wading birds would also benefit from:

- management strategies that protect and maintain important existing habitat areas,
- project wetlands and wading bird nesting areas,
- improve habitat quality for shorebirds and wading birds.

Such strategies could be implemented through cooperative agreements with land management agencies or through conservation easements or purchase from willing sellers.

Restoration of ecosystem processes and habitats proposed by ERPP in other ecological zones will also allow natural floodplains, meander corridors, seasonal pools, and riparian vegetation to develop that will provide habitat for these species elsewhere in the Central Valley.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Other existing programs that will directly or indirectly improve and restore habitat for shorebirds and wading birds include:

- Bay Area Wetlands Planning Group,
- Central Valley Habitat Joint Venture,
- Cosumnes River Preserve,
- Grizzly Slough Wildlife Area,
- San Francisco Bay National Wildlife Refuge,
- Sonoma Baylands Project,
- Tidal Wetlands Species Recovery Plan,
- Yolo Basin Wetlands Project, and
- San Francisco Bay Wetlands Ecosystem Goals Project.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Protection and restoration of shorebirds and wading birds is integrally linked with restoration of perennial aquatic, wetland, and riparian habitats and reduction in human disturbance.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

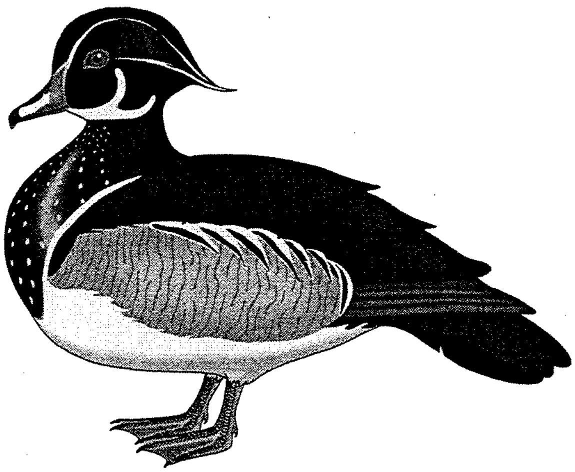
The implementation objective for the shorebird and wading bird guild is to maintain healthy populations in order to contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of land and water in the Bay-Delta.

The following general targets will assist in meeting the implementation objective:

- Increase the number of shorebirds and wading birds over present levels.
- Increase the distribution of shorebirds and wading birds.
- Increase the quantity and quality of overwintering and resting habitat.

The following general programmatic actions will assist in meeting the targets:

- Increase the amount of riparian habitat in the Central Valley.
- Increase the amount of perennial aquatic habitat in the Central Valley.
- Increase the amount of emergent and seasonal wetlands in the Central Valley.
- Improve water management and land use practices to benefit wading birds' and shorebirds.
- Limit disturbance to nesting, roosting, and foraging habitats.



INTRODUCTION

Central Valley waterfall populations are a highly valued and diversified biological resource and are found in all ecological zones within the study area. Large numbers of ducks, geese, and swans winter in the Central Valley after migrating from northern breeding areas. Some species, such as the mallard, gadwall, and Canada goose, are also year-long residents and breed locally in wetlands and nearby uplands. Waterfowl are a significant component of the ecosystem, are of high interest to recreational hunters and bird watchers, and contribute to California's economy through the sale of hunting and related equipment. Historical waterfowl wintering habitat areas have declined by approximately 95% and, as a result of substantial losses of wetland and grassland habitats, waterfowl breeding populations have declined from historical levels.

Major factors that limit this resource's contribution to the health of the Delta are related to adverse effects of conversion of wetland and grassland habitats to agricultural, industrial, and urban uses.

RESOURCE DESCRIPTION

Migration over long distances requires a great amount of energy. Upon arrival to wintering grounds, waterfowl depend on high-quality foraging habitat with sufficient grains, insects, and aquatic plants to replenish their energy reserves. These habitats include seasonal, permanent, tidal, and agricultural wetlands; deepwater; riparian woodlands; grasslands; and agricultural uplands and other associated habitats.

Recent declines in waterfowl populations are attributed primarily to the cumulative degradation or loss of breeding, wintering, and foraging habitats in the Central Valley and outside of California. Population declines are most likely caused by a combination of factors that have reduced or eliminated important ecosystem processes. These factors include:

- loss of natural wetlands because of altered flow regimes, resulting in the loss of natural floodplains;
- fragmentation or loss of large areas of wetlands as a result of land reclamation;
- loss of shallow-water habitat as a result of flood management practices;
- loss of riparian habitat resulting from channelization and levee protection practices;
- loss of tidal wetlands as a result of dikes and levees fro flood control;
- heavy metal contamination from sources such as subsurface agriculture drainage; and
- loss of the natural mosaic of habitats required to meet the life requirements of waterfowl.

Many other factors have also contributed to the decline of waterfowl, although perhaps to a lesser degree. These include high concentrations of waterfowl in relatively small areas, which exposes greater portions of the population to diseases (such as botulism and cholera) and predation on nests and young by non-native species. Other factors that can affect waterfowl populations, such as extended periods of drought, are natural and will remain.

VISION

The vision for waterfowl is to maintain healthy populations at levels that can support consumptive (e.g., hunting) and nonconsumptive (e.g., birdwatching) uses.

Protecting existing and restoring additional suitable seasonal, permanent, and tidal wetlands; deepwater; riparian woodlands; and grasslands; and other associated habitats and improving agricultural land management and reducing the effect of breeding stressors will be critical to maintaining healthy waterfowl populations in the Bay-Delta. Large-scale restoration of nesting, brood, and foraging habitat will help to reduce predation on nests and young. Diverse and wide-spread habitats decrease the likelihood of large-scale outbreaks of disease. Habitat restoration in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones will help to maintain healthy populations of waterfowl by increasing the quality and quantity of habitats used by these species.

Efforts under existing migratory bird management programs have significantly improved critical habitats, including water management for seasonally managed agriculture fields, development of permanent habitat on federal refuges in the State wildlife areas, and incentives for private landowners to provide wintering habitat for migratory waterfowl.

Restoration of ecosystem processes and habitats proposed by ERPP in other ecological zones will also allow floodplain wetland, riparian, and upland habitats to develop that will provide habitat for waterfowl elsewhere in the Central Valley.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Some of the programs that are restoring populations and habitat for waterfowl in the study area include:

- Upper Sacramento River Fishery and Riparian Habitat Council (SB 1086) Program,
- Suisun Marsh Protection Plan,
- California Department of Fish and Game wildlife areas,
- U.S. Fish and Wildlife Service refuges,
- The Nature Conservancy's Jepson Prairie Preserve,
- Ducks Unlimited Valley Care Program
- California Waterfowl Association,
- Cache Creek Corridor Restoration Plan,
- Putah Creek South Fork Preserve,
- Woodbridge Ecological Reserve,
- Yolo County Habitat Conservation Plan, and
- Central Valley Habitat Joint Venture

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Protection and restoration of waterfowl populations is integrally linked with restoration of perennial aquatic, wetland, tidal slough, riparian, grassland, and agricultural habitats and reduction in contaminants such as selenium in Central Valley breeding and wintering areas.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

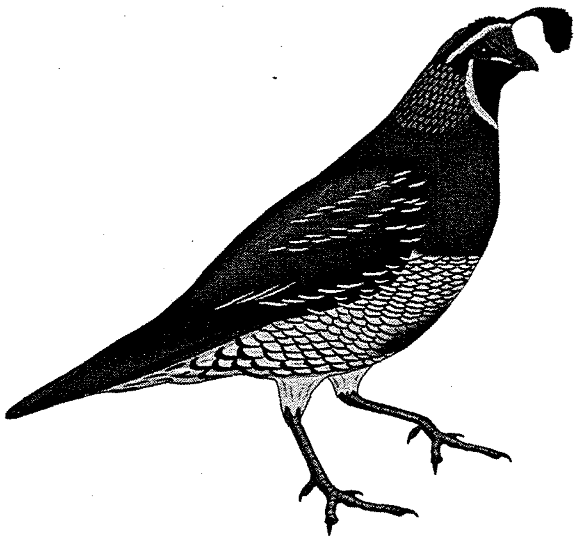
The implementation objective for waterfowl is to maintain healthy populations at levels that can support both consumptive and nonconsumptive uses consistent with the goals and objectives of the Central Valley Habitat Joint Venture and the North American Waterfowl Management Plan and contribute to the overall health and beneficial uses of the Bay-Delta.

The following general targets will assist in meeting the implementation objective:

- Increase waterfowl populations, and
- Increase distribution of waterfowl.

The following general programmatic actions will assist in meeting the targets:

- implementing management strategies to protect important existing habitat areas,
- increasing the quantity and quality of breeding habitat and forage on agricultural land,
- establishing new programs or expanding existing programs to provide incentives for landowner participation,
- restoring and improving wetlands in conjunction with adjacent herbaceous uplands to improve breeding habitat,
- expanding existing State and Federal wildlife areas by creating additional wetland complexes,
- improving water quality, and
- establishing programs that allow government agencies and waterfowl conservation organizations to work cooperatively to increase the efficiency of existing strategies and waterfowl management plans.



INTRODUCTION

Upland game species are of high interest to recreational hunters in the Bay-Delta and contribute to California's economy through the sale of hunting-related equipment and hunting-related expenditures. Major factors that limit this resource's contribution to the health of the Delta are related to adverse effects of conversion of native upland habitats for agricultural, industrial, and urban uses, and land use practices that degrade habitats used by these species.

RESOURCE DESCRIPTION

The upland game guild includes those species defined in the California Department of Fish and Game (DFG) hunting regulations as resident and migratory upland game birds and small game. Of the three groups of upland game species that define the guild (Coastal and Central Valley, Mountain Upland, and Eastern Upland), only the coastal and Central Valley group (Table 4) is addressed in this vision. The montane upland game group includes species that typically inhabit the upper elevations of the Coast Ranges, Cascade Range, and Sierra Nevada. The eastern upland game group includes those species inhabiting the eastern slopes of the Sierra Nevada and eastern high deserts within California.

Upland game species commonly occur in upland habitat types, including agricultural cropland, riparian habitats, and oak woodlands. The ring-necked pheasant and wild turkey are non-native species that have successfully established in the Central Valley and are popular game for hunting. These species occur from the Central Valley floor to the foothills. Native species' population densities, with the exception of the American crow, are currently lower than they were before lands in the Bay-Delta were reclaimed. Native species are an integral part of our heritage, providing recreation and food for thousands of people. Their populations are good indicators of the health and viability of the vegetative communities on which they rely.

Throughout California, upland game habitat has been degraded or lost as a result of some types of land uses, such as logging, land conversion, water projects, intensive farming, overgrazing, and urban encroachment. Wildfires and floods also destroy many acres of nesting and escape cover.

VISION

The vision is to maintain healthy populations of upland game species at levels that can support both consumptive (e.g., hunting) and nonconsumptive (e.g., birdwatching) uses, through protection and improvement of habitats and reduction in stressors.

Protecting and restoring existing and additional suitable grassland, seasonal and emergent wetland, midchannel island and shoal, and riparian habitats, and improving management of agricultural lands and reducing the effect of stressors that can suppress breeding success will be critical to maintaining healthy upland game populations in the Bay-Delta. The ERPP's proposed habitat restoration in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones will increase habitat quality and quantity. Restoration will also help maintain healthy populations of upland game species.

Restoring upland game habitat over a range of elevations above Bay-Delta mean-high-tide water levels would allow a greater diversity of plant species to establish.

Upland game species would also benefit from management strategies that would improve habitat quality. Management strategies should include protecting and maintaining important existing habitat areas and encouraging establishment and maintenance of agricultural and upland habitats used by these species. Such strategies could be implemented through cooperative agreements with land management agencies, landowner incentive programs, or conservation easements with or purchase from willing sellers.

Restoration of ecosystem processes and habitats that allow natural floodplains, meander corridors, seasonal pools, and riparian vegetation to develop will provide habitat for upland game species elsewhere in the Central Valley.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Groups that are involved in efforts to restore upland game include:

- DFG game management,
- Pheasants Forever,
- Turkey Federation, and
- Quail Unlimited.

DFG's Game Bird Heritage Program continues to actively improve upland game habitat and hunting opportunities throughout the State.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Protection and restoration of upland game species is integrally linked with restoration of riparian, grassland, and agricultural habitats, as well as improvements in upper watershed health.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for upland game is to maintain healthy populations at levels that can support both consumptive and nonconsumptive uses.

The following general targets will assist in meeting the implementation objective:

- Increase upland game populations.
- Improve hunting opportunities.

The following general programmatic actions will assist in meeting the targets:

- Protect and restore upland habitats.
- Improve land use and agricultural land management to enhance upland game.
- Improve forest and riparian land management for upland game.
- Reduce potential for wildfire in floodplain, riparian forest, grasslands, and forest lands.

Upland Game Species and the Groups in Which They Appear

Species	Coastal and Central Valley Group	Montane Upland Game Group	Eastern Upland Game Group
Ring-necked pheasant	X		
California quail	X		X
Wild turkey	X	X	
Common snipe	X	X	X
Dove	X	X	X
American crow	X	X	X
Tree squirrels	X	X	X
Cottontail/brush rabbit	X	X	X
Black-tailed hare	X	X	X
Band-tailed pigeon	X	X	X
Chukar*		X	X
Mountain quail*		X	X
Sage grouse*			X
Blue/ruffed grouse*		X	
Ptarmigan*		X	

*These species are not addressed by this vision.

INTRODUCTION

Neotropical species breed in North America and winter in Central and South America. Many species of neotropical migratory birds migrate through or breed in the Bay-Delta. These species are a significant component of the ecosystem. These species are of high interest to recreational bird watchers, and contribute to California's economy through sales of equipment and other bird-watching-related expenditures. There have been substantial losses of historic habitat used by these species and available information suggests that population levels for many of these species is declining.

Major factors that limit this resource's contribution to the health of the Delta are related to adverse effects of conversion of native habitats for agricultural, industrial, and urban uses, and land use practices that degrade habitats used by these species.

RESOURCE DESCRIPTION

The neotropical migratory bird guild comprises bird species that breed in North America and winter in Central and South America. Representative species of the neotropical migratory bird guild are the western kingbird, western wood-pewee, tree swallow, cliff swallow, northern oriole, Wilson's warbler, and yellow-breasted chat. Individual visions are developed for some neotropical migrants, such as the Swainson's hawk and yellow-billed cuckoo, and those visions contain more specific targets relating to those species. All species of the neotropical migratory bird guild depend on the flora of California to forage and reproduce, typically from about May until September. The birds normally spend the rest of the year in Central and South America.

Neotropical birds occur throughout the California and are associated with most of California's habitat types, including forested woodlands, riparian and montane riparian habitats, unforested lowlands, grasslands, shrub habitats, valley foothill hardwood, valley foothill hardwood-conifer, and wetlands. Population levels of many of these species has declined, primarily as a result of the loss and degradation of habitats on which they depend, both in California and on their Central and South American wintering areas. In California, the quality and quantity of important neotropical migrant bird habitats have been substantially reduced primarily by their conversion to agricultural, industrial, and urban uses, and land use practices that degrade the values provided by these habitats.

VISION

The vision for the neotropical migratory bird guild is to maintain and increase healthy populations of neotropical migratory birds through restoring habitats on which they depend.

Protecting existing and restoring additional suitable wetland, riparian, and grassland habitats will be critical to maintaining healthy neotropical migrant bird populations in the Bay-Delta. Large-scale restoration of nesting habitat will help reduce nest parasitism and predation by creating habitat conditions that render neotropical birds less susceptible to these stressors. Restoration of these habitats in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones will help maintain healthy populations by increasing the quality and quantity of habitats used by these species. Restoration of ecosystem processes and habitats in other ecological zones will also allow natural floodplains, stream meanderings, seasonal pools, and riparian vegetation to develop that will provide habitat for these species elsewhere in the Central Valley.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Related restoration programs include:

- Central Valley Project Improvement Act,
- Cache Creek Corridor Restoration Plan,
- Cosumnes River Preserve,
- Riparian Habitat Joint Venture,
- Upper Sacramento River Advisory Council's Riparian Habitat Committee (SB1086 program),
- San Joaquin River Management Program, and
- U.S. Fish and Wildlife Service's Anadromous Fish Restoration Plan.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration of neotropical migratory birds is integrally linked with restoration of wetland, riparian, grassland, and forest habitats.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for the neotropical migratory bird guild is to maintain healthy populations to contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of land and water in the Bay-Delta.

The following general targets will assist in meeting the implementation objective:

- Increase populations of neotropical birds in the Central Valley.
- Increase the distribution of neotropical birds in the Central Valley.

The following general programmatic actions will assist in meeting the targets:

- Increase wetland, riparian, grassland and habitats in the Central Valley.
- Improve upper watershed health.
- Improve specific nesting habitats for individual species within their existing and restored habitats.
- Protect nesting habitats from predators and human disturbance.

LANGE'S METALMARK, DELTA GREEN GROUND BEETLE, AND VALLEY ELDERBERRY LONGHORN BEETLE

INTRODUCTION

The Lange's metalmark, a federally listed endangered species, the delta green ground beetle and the valley elderberry longhorn beetle (VELB), both federally listed threatened species, are respectively associated with inland dune, vernal pool, and riparian habitats. The distribution and populations of these species have declined substantially, primarily as a result of the loss or degradation of these habitats within their range. The loss of habitat and declining condition of these species populations have warranted their listing as threatened or endangered under the federal Endangered Species Act.

Major factors that limit this resource's contribution to the health of the Delta are related to adverse effects of conversion of native habitats for agricultural, industrial, and urban uses, and land and water management practices that degrade habitats used by these species.

RESOURCE DESCRIPTION

The preferred habitat of Lange's metalmark, a butterfly, is inland dune scrub. The Lange's metalmark is dependent on its host plant, naked buckwheat. The present range of Lange's metalmark has been reduced to about 70 acres of suitable habitat within the Antioch Dunes National Wildlife Refuge and on a few small parcels of privately held land on the eastern flank of the refuge. Over a 9-day sampling period in 1977, biologists estimated that only 400 adult butterflies remain at the Little Corral site. From 1986 to 1991, the population increased exponentially, from approximately 160 butterflies to nearly 2,000. In 1992, the population fell to about one-third of the peak level, but by 1996 had recovered to more that 2,000 butterflies. A wide variety of stressors (e.g., land use, wildfire, non-native plant species, sand mining, fences, and human-related disturbance) that degrade this species' habitat have contributed to the endangered status of Lange's metalmark.

The delta green ground beetle is found at the Jepson Prairie Preserve in Solano County, which is in the Yolo Basin Ecological Zone. The delta green ground beetle and its soft-bodied prey species are most often observed on moist environments such as those provided by Olcott Lake and vernal pools within the Jepson Prairie Preserve. Vernal pools and aquatic seasonal habitats supply the critical needs of the delta green ground beetle. Entomologists believe that appropriate conditions for the species are found in open, moist habitats with limited vegetative cover.

Since 1974, entomologists have seen or collected only 75 adult delta green ground beetles in the preserve area. Although the historical distribution of the delta green ground beetle is unknown, the widespread disruption of wetland and grassland habitats in the Central Valley over the last 150 years strongly suggests that the range of the beetle has been reduced and fragmented. Today, the beetle predominately inhabits the borders of vernal pools and Olcott Lake at the Jepson Prairie Preserve. The primary threats to the survival of the delta green ground beetle have been, and continue to be, loss and alteration of its wetland habitat primarily because of agricultural conversion (i.e., the plowing and leveling of land); grazing; river channelization; and construction of dams, drainage ways, and pipelines.

VELB has been found only in association with its host plant, elderberry (*Sambucus* spp.). Elderberry is a component of the remaining riparian forests and adjacent grasslands of the Central Valley. Entomologists estimate that the range of this beetle extends from Redding at the northern end of the Central Valley to the Bakersfield area in the south.

Important stressors on VELB are fragmentation of riparian habitat; grazing; and excessive collection of the species for commercial, recreational, scientific, or educational purposes. Local populations can also be severely damaged by pesticides inadvertently drifting from nearby agricultural lands into occupied habitat areas.

VISION

The vision for the Lange's metalmark, the delta green ground beetle, and VELB is to assist in maintaining the existing Lange's metalmark population and by maintaining its abundance, and to assist in the recovery of the delta green ground beetle and VELB by increasing their populations and abundance through habitat restoration.

Protecting existing and restoring additional suitable inland dune scrub habitat will be critical to maintaining and increasing the abundance of the Lange's metalmark population in the Bay-Delta. Habitat restoration in the Sacramento-San Joaquin Delta Ecological Zone will help maintain healthy populations by increasing the quality and quantity of this species habitat.

Protecting existing and restoring additional suitable seasonal wetlands, including vernal pools, and associated grasslands will be critical to recovery of the delta green ground beetle in the Bay-Delta. Restoration of these habitats in the Sacramento-San Joaquin Delta Ecological Zone will help maintain healthy populations by increasing the quality and quantity of habitats used by this species.

The delta green ground beetle would also benefit from cooperative management strategies with The Nature Conservancy's Jepson Prairie Preserve.

Protecting existing and restoring additional suitable riparian habitats and establishing new populations will be critical to recovery of the VELB in the Bay-Delta. Restoration of riparian habitats in the Sacramento-San Joaquin Delta Ecological Zone will help maintain healthy populations by increasing the quality and quantity of habitats used by these species.

The period required to achieve recovery of the VELB could be reduced by introducing the species into unoccupied or restored habitat areas. Such a strategy could be implemented through cooperative agreements with land management agencies or cooperative agreements with willing landowners. The VELB would also benefit from development and implementation of alternative designs for and maintenance of flood control, bank protection, and other structures that reduce their potential adverse effects on existing riparian habitats.

Restoration of ecosystem processes and habitats in other ecological zones will also allow riparian vegetation to develop that will provide habitat for these species elsewhere in the Central Valley. The benefit of these restorations for recovery of the VELB would be increased by implementing restoration of riparian habitats in a manner that links isolated areas supporting existing VELB populations.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

There are a number of programs that involve these species:

- U.S. Fish and Wildlife Service,
- California Department of Fish and Game (DFG),
- California State Parks and Recreation,
- Riparian Habitat Joint Venture,
- DFG's Calhoun Cut Reserve, and
- TNC's Jepson Prairie Preserve.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Restoration of these species is integrally linked with restoration of seasonal wetland, riparian, inland dune, perennial aquatic, and grassland habitats in the Central Valley and are adversely influenced by the detrimental effects of invasive plant species.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective is to assist in maintaining populations of the Lange's metalmark, a federally listed endangered species, by increasing its abundance, and assist in the recovery of the delta green ground beetle, a federally listed threatened species, and Valley elderberry longhorn beetle, a federally listed threatened species, by increasing their populations and abundance. Meeting this objective would contribute to overall species richness and diversity and reduce conflict between the need for their protection and other beneficial uses of land and water in the Bay-Delta.

The following general targets will assist in meeting the implementation objective:

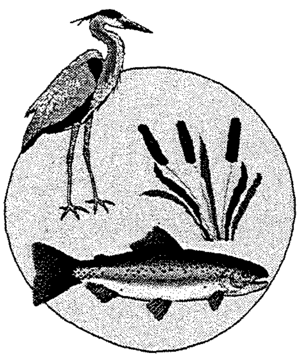
- Increase the number and distribution of Lange's metalmark.
- Increase the numbers and distribution of delta green ground beetle.
- Increase the numbers and distribution of valley elderberry longhorn beetle.

The following general programmatic actions will assist in meeting the targets:

- Protect and restore wetland, riparian, and grassland habitat.
- Implement control measures to eradicate invasive plant species.
- Increase the amount of inland dune scrub habitat.
- Develop cooperative management strategies with the Antioch Dune Ecological Reserve that protect and and manage existing habitat areas.
- Maintain healthy populations of naked buckwheat within inland dune scrub habitats.
- Enhance the formation of active dunes by such means as importing clean sand of appropriate dimensions, reducing stabilizing vegetation, and increasing topographic relief, dune height, and the frequency of steep north/northwest facing erosional slopes with sparse vegetation cover.
- Design and manage restored seasonal wetlands and grasslands near delta green ground beetle populations to improve habitat quality for the species.
- Introduce species into unoccupied or restored habitat areas.
- Reduce land and water management practices that degrade habitats used by these species.

VISION FOR REDUCING OR ELIMINATING STRESSORS

INTRODUCTION



This section presents visions for stressors that adversely affect important ecosystem elements. Stressors are natural and unnatural events or activities that adversely affect ecosystem processes, habitats, and species. Environmental stressors include water diversions, water contaminants, levee confinement, stream channelization and bank armoring, mining and dredging in streams and estuaries, excessive harvest of fish and wildlife, introduced predator and competitor species, and invasive plants in aquatic and riparian zones. Some major stressors affecting the ecosystem are permanent features on the landscape, such as large dams and reservoirs that block transport of the natural supply of woody debris and sediment in rivers or alter unimpaired flows. Reducing the adverse effects of stressors is a major component in the Ecosystem Restoration Program Plan (ERPP). Stressors addressed have a strong effect on an ecological process, habitat, or a species that is dependent on the Bay-Delta and can be feasibly and sufficiently reduced to improve the health of the Bay-Delta ecosystem. Table 11 identifies important stressors and the related ERPP implementation objective. Implementation objectives are fixed and will not change through time. Table 12 presents the basis for their selection as an ecosystem stressor. The broad stressor, land use, is addressed as an element of all stressor visions.

These visions describe the locations where the stressor has a substantial adverse effect in the ERPP area, and how each stressor affects ecological processes, habitats, and/or species. Restoration needs to reduce the adverse effects of stressors are also identified. The Ecosystem Restoration Program Plan, Volume II: Ecological Zone Visions contains more detailed objectives, targets, and programmatic actions for each stressor as it relates to a specific ecological zone. Table 13 identifies which zones address which stressors.

TABLE 11. STRESSORS AND ERPP IMPLEMENTATION OBJECTIVES

Stressor Type	Implementation Objective
Water Diversions	reduce entrainment of all life stages of fish into water diversions in order to increase survival and population abundance to levels that contribute to the overall health of the Delta and reduce conflicts for other beneficial uses of land and water.
Dams, Reservoirs, Weirs, and Other Structures	increase the quality and dependability of migration corridors connecting upstream spawning and rearing habitat with the mainstem rivers in the Sacramento-San Joaquin basin in order to increase success of adult spawners and survival of juvenile downstream migrants.
Levees, Bridges, and Bank Protection	reestablish or reactivate geomorphological processes in artificially confined channel reaches to maintain hydrologic connectivity with the natural floodplain.

Stressor Type	Implementation Objective
Dredging and Sediment Disposal	reduce loss and degradation of aquatic habitat and vegetated berm islands caused by dredging activities and reduce impacts of dredging activities on aquatic resources during critical spawning and rearing periods and in sensitive areas.
Gravel Mining	reduce the adverse effects of instream gravel mining to improve gravel recruitment, cleansing, and transport processes, contribute to natural stream sediment supply, and improve other stream channel processes.
Invasive Aquatic Plants	reduce the adverse effects of these species on native plants to increase and maintain the productivity of the aquatic foodweb, preserve suitable fish habitat structure, and provide quality habitat conditions for native submergent and emergent plants.
Invasive Aquatic Organisms	reduce introductions of non-native species in order to protect and provide sustainable populations of native species.
Invasive Riparian and Salt Marsh Plants	reduce populations of invasive non-native tree and shrub species that compete with native riparian vegetation.
Non-Native Wildlife	reduce the abundance of non-native wildlife species to maintain and expand the diversity or abundance of native species or the ecological stability of native habitats.
Predation and Competition	reduce the loss of juvenile anadromous and resident fish and other aquatic organisms from unnatural levels of predation in order to increase survival and contribute to the restoration of important species.
Contaminants	reduce concentrations and loading of contaminants in the aquatic environment and the subsequent bioaccumulation by aquatic species, increase survival of aquatic species, and eliminate public health concerns resulting from accumulation of toxins in tissues.
Fire	reduce the acreage and frequency of catastrophic wildfires to reduce their adverse effects on fish and wildlife and their habitats.
Fish and Wildlife Harvest	regulate harvest of fish and wildlife to the extent necessary to avoid impairing the reproductive capacity of the population in relation to available habitat.
Artificial Fish Propagation	reduce the potentially adverse effects of stocking artificially produced fish throughout Central Valley rivers and streams in order to increase the survival of naturally produced fish, contribute to long-term restoration goals, and maintain the genetic diversity of naturally producing populations of chinook salmon and steelhead populations.
Disturbance	reduce human activities that adversely affect wildlife behavior or cause habitat destruction, increase reproductive success, and contribute to restoration of important species.

TABLE 12. BASIS FOR SELECTION OF STRESSOR ECOSYSTEM ELEMENTS

Stressors	Basis for Selection as an Ecosystem Element
Water Diversions	Diversions cause loss of water, nutrients, sediment, and organisms (entrainment). The transfer of water across the Delta through existing channels may also detour migrating resident, estuarine, and resident fish species from their primary routes. The diversion rate also contributes to reduced water residence time which reduces primary (plant) and secondary (animal) production and standing biomass.
Dams, Reservoirs, Weirs, and Other Structures	Dams block fish movement, alter water quality, remove fish and wildlife habitat, and alter hydrological and sediment processes. Other human-made structures may block fish movement or provide habitat or opportunities for detrimental predatory fish and wildlife.
Levees, Bridges, and Bank Protection	Levees, bridges, and bank protection structures inhibit overland flow and erosion and depositional processes that develop and maintain floodplains, and allow stream channels to meander. Levees prevent floodflows from entering historic floodplains, and eliminate or alter the character of floodplain ecosystem processes and habitats. Channelizing floodflows also increases scour or incision and reduces or halts channel meander and oxbow formation. Bridges have a similar, though generally more localized effect.
Dredging and Sediment Disposal	Dredging in Bay-Delta waters may damage aquatic habitat or harm aquatic animals and plants. Channel dredging also contributes to levee instability and steepens channelbanks which increases shoreline habitat erosion.
Gravel Mining	Mining sand and gravels from rivers and floodplains may affect natural sediment supply, gravel movement, and sediment deposition. Sand, gravel, and sediment distribution influences the quality of wildlife habitat, abundance of aquatic predators, water quality and fish and wildlife populations. Excessive instream mining could result in riparian corridor instability.
Invasive Aquatic Plants	Invasive aquatic plants may have an adverse effect on native aquatic plants, constrain habitat quality of water ways, require control measures, and impair water conveyance systems and use of fish protective devices such as fish screens.
Invasive Aquatic Organisms	Invasive aquatic organisms may have an adverse effect on the foodweb and on native species resulting from competition for food and habitat and direct predation.

Stressors	Basis for Selection as an Ecosystem Element
Invasive Riparian and Salt Marsh Plants	Restoration of native riparian and salt marsh plants and plant communities can be hindered by introduced species which may outcompete or displace native plant species. Non-native plant species may have little value to wildlife and other riparian dependent species.
Non-native Wildlife	Introductions of non-native species may adversely affect the survival of native wildlife. Non-native wildlife has greatly altered ecological processes, functions, habitats, species diversity, and abundance of native plants, fish, and wildlife.
Predation and Competition	Unnatural levels of predation and competition may adversely affect populations of fish and wildlife.
Contaminants	Contaminants affect water quality and the survival of fish, waterfowl, and the aquatic foodweb.
Fire	Wildfires caused from unnaturally high fuel levels in tributary watersheds of the Bay-Delta threaten water supply and fish and wildlife habitat through deforestation. Deforestation results in excessive erosion and surface runoff.
Fish and Wildlife Harvest	Fish and wildlife harvest may affect abundance of species or viability of local populations.
Artificial Fish Propagation	Fish hatcheries and other artificial propagation programs (e.g., pen-rearing salvaged striped bass) may adversely affect populations of "wild" fish. Direct effects might be predation on wild fish or competition from artificially-produced fish. Indirect effects may occur from adverse changes in wild population genetics from interbreeding with hatchery fish. Disease may also be transferred from hatchery fish to wild fish.
Disturbance	Boating, habitat disturbance, and other negative anthropogenic activities may adversely affect wildlife habitat and species abundance and distributions.

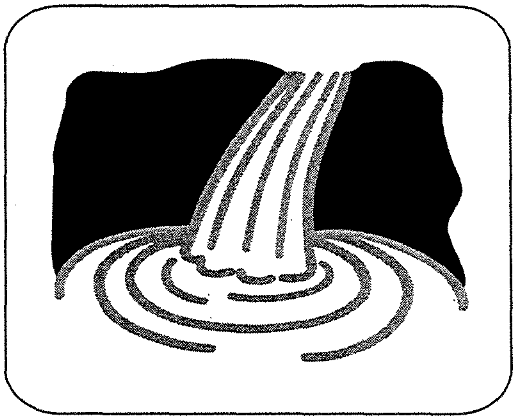
TABLE 13. ECOLOGICAL ZONES IN WHICH IMPLEMENTATION OBJECTIVES, TARGETS, AND PROGRAMMATIC ACTIONS TO REDUCE STRESSORS ARE PROPOSED

[Note: Refer to Volume II: Ecological Zone Visions for information regarding specific targets and actions.]

Stressors	Ecological Zone[a]													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Water Diversions	●	●	●	●			●	●	●	●	●	●	●	
Dams, Weirs, Reservoirs, and Other Structures			●	●			●	●			●		●	
Levees, Bridges, and Bank Protection	●		●						●			●		
Dredging and Sediment Disposal	●													
Gravel Mining				●	●					●				
Wildfire														
Non-native Species	●	●	●	●					●	●	●			
Predation and Competition	●	●	●							●	●		●	
Contaminants	●	●	●			●			●	●	●	●		●
Fish and Wildlife Harvest	●	●	●	●			●	●	●		●		●	
Artificial Fish Propagation			●	●			●	●	●		●		●	
Disturbance	●	●												

Ecological Zones

[a] 1 = Sacramento-San Joaquin Delta
2 = Suisun Marsh/North San Francisco Bay
3 = Sacramento River
4 = North Sacramento Valley
5 = Cottonwood Creek
6 = Colusa Basin
7 = Butte Basin
8 = Feather River/Sutter Basin
9 = American River Basin
10 = Yolo Basin
11 = Eastside Delta Tributaries
12 = San Joaquin River
13 = East San Joaquin Basin
14 = West San Joaquin Basin



INTRODUCTION

Water diversions are found throughout Central Valley rivers and their tributaries, the Bay and Delta. Water is diverted for irrigated agriculture, municipal and industrial use, and managed wetlands.

Water diversions in the Bay-Delta watershed directly and indirectly affect fish, aquatic organisms, sediments, streamflow, habitat, foodweb productivity, and species abundance and distribution. The rate of diversion from the Delta affects residence time of water which, in turn, affects primary (plant) and secondary (animal) production.

Factors that relate to the influence that diversions have on the health of the Bay-Delta ecosystem health include diversion rate, the season in which water is diverted, the diversion location, fish species, fish life stage periodicity, and whether the diversion is equipped with adequate fish protection facilities.

In most cases, entrained organisms do not survive. Some diversions have screens that exclude most juvenile and adult fish; however, eggs and larval fish, invertebrates, planktonic plants, organic debris and dissolved nutrients are lost to diversions.

STRESSOR DESCRIPTION

Water diversion in the Bay-Delta and its watershed may vary by water year type and month of the year, and has a wide variety of effects on streamflow, aquatic organisms, habitat, and ecosystem processes. In some cases, diversions on a tributary stream remove so much flow during summer and fall that little or no flow remains in the stream.

Along the mainstem Sacramento River the following diversions exist:

- The Red Bluff Diversion Dam (RBDD) diverts Sacramento River water into the Tehama-Colusa Canal and the Corning Canal.
- The Anderson-Cottonwood Irrigation District (ACID) Diversion Dam diverts water into the ACID canal.
- The Glenn-Colusa Irrigation District's (GCID's) Hamilton City Pumping Plant. With a diversion capacity of 3,000 cubic feet per second (cfs) it is the largest diversion on the Sacramento River.
- Several hundred smaller diversions exist along the Sacramento River, more than 2,000 diversions exist in the Delta, and about 150 diversions exist in the San Joaquin.

The largest diversions have fish screens and require frequent, routine maintenance to provide consistent levels of fish protection. The effectiveness of screes is dependent on may factors, including maintenance, design, and site-specific physical conditions. A well-designed fish screen based on proved technology is effective in reducing entrainment and impingement losses of many species of juvenile fish. Screen retrofits can be fairly inexpensive, especially on smaller-sized diversions.

In the south Delta, the two largest diversions are operated by the State Water Project (SWP) and federal Central Valley Project (CVP). These two large diversions have louvers that guide juvenile fish into bypasses and holding facilities, where salvaged fish are collected and transported back to the Bay and Delta. Many fish are salvaged. Nevertheless, many more are lost to handling, predation and to bypass inefficiency during collection and holding at the fish facilities, or during fish transport. Programs to upgrade these fish protection facilities are ongoing.

Two large fossil fuel power plants are operated in the Bay-Delta, one at Antioch and one at Pittsburg. Each has large, screened intake systems. The screens, however, use 1950s technology and do not effectively screen larvae or small juvenile fish. Although the power plants return the water to the Delta, many entrained larvae and juveniles are killed by mechanical damage or heat stress. Survival rates have been measured only for striped bass and under many conditions, approximately 80% passing through the plant survive.

The Contra Costa Water District has several diversions in the Bay-Delta. They sporadically operate a diversion at Mallard Slough in Suisun Bay. New screens are in place at the new Los Vaqueros diversion on Old River. New screens are being constructed at the Contra Costa Water District Rock Slough intake.

In Suisun Bay and Suisun Marsh, far fewer agricultural diversions exist because of brackish waters. However, many State and privately managed wetlands divert water seasonally from Suisun Marsh sloughs. The larger diversions at Roaring River, Grizzly Slough, and Island Slough are screened. The smaller diversions are unscreened gates, siphons, or pumps. Recently, the Suisun Resource Conservation District (SRCD) and California Department of Fish and Game (DFG) began a program to screen some diversions with self-cleaning, fine-mesh screens.

VISION

The vision for water diversions is to reduce the adverse effects of water diversions, including entrainment of aquatic organisms. Achieving this vision will assist in the recovery of State- and federally listed fish species, improve important sport fisheries, and improve the Bay-Delta aquatic foodweb.

This vision concentrates on the direct effects of aquatic organism entrainment. Cumulatively, water diversions remove large numbers of young salmon, steelhead, delta smelt, splittail, striped bass, and many other fishes and invertebrates from the rivers, Delta, and Bay.

Approaches to achieving this vision include reducing their adverse effects by removing or relocating high impact diversions. Altering the timing of some diversions would help to reduce losses of aquatic organisms. Installing positive-barrier fish screens would help to reduce losses.

On much of the Sacramento and San Joaquin rivers and their tributaries, diversions entrain juvenile salmon and steelhead in spawning and rearing areas, and on their migrations downstream toward the ocean. Adequate positive barrier fish screens will protect juvenile salmon and steelhead from being entrained. Positive barrier fish screens can be employed at most of the tributary diversion sites.

Screen upgrades continue to improve screening efficiency for the large diversions along the Sacramento River, such as those of ACID, RBDD, and GCID. The Red Bluff Research Program is studying alternatives, including pumping from the river and returning entrained salmon and steelhead to the river through a bypass system. Positive-barrier screens that move fish through a bypass are also being considered for large diversions such as GCID.

The Delta Fish Facilities Technical Team is focusing on reducing entrainment losses at the south Delta pumping plants through the use of positive barrier fish screens. Salvage facilities at SWP and CVP diversions do not provide adequate fish protection, especially for small, fragile species like delta smelt.

The technical team is currently considering two parallel approaches. The first is to upgrade the screening systems of the existing facilities. The second is to provide an alternative intake location, such as in the north Delta, where entrainment losses would be less and fewer fish would be drawn into the Central and South Delta. In the north Delta, bypass collectors can return fish to the river. In the south Delta, collected fish must be transported, as with the existing south Delta facility, to western Delta or Bay locations.

Using self-cleaning cylindrical screens on small Bay-Delta siphons and pump diversions appears feasible. In Suisun Bay and Suisun Marsh, use of either positive-barrier flat screens or conical screens on slough intakes (e.g., Roaring River diversion) has proven effective.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Working with individual diverters would achieve the vision to provide them with alternative sources of water, moving their intakes, revising their diversion schedules, or funding installation of screened intakes.

Efforts to reduce impacts of unscreened diversions in the Bay-Delta and its watershed will involve cooperation among several agencies' screening programs including DFG's Unscreened Diversion Program, Anadromous Fish Screen Program of the CVPIA, and NRCS's Fish Screen Program. Recently, Reclamation Districts 108 and 1004, and Princeton-Codora-Glenn/Provident Irrigation District and other large diverters are either installing new screens or have begun the engineering needed to install screens. Hundreds of smaller diversions along the river consist of siphons or pumps; most of these are unscreened. The CVPIA Anadromous Fish Screen Program will contribute to the screening of many of these diversions on a cost-share basis. Cooperation will also be sought with agencies having responsibility or authority for dealing with screening diversions, including DFG, DWR, Reclamation, State Water Resources Control Board, NRCS, NMFS, and the U.S. Army Corps of Engineers.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Water diversions are closely linked to other ecosystem elements including processes, habitats, and species. For example, the diversion of large quantities of water in the Delta also results in the diversion of sediments, nutrients, and many lower level organisms in the Bay-Delta aquatic food chain. The management of water in the ERPP study area, particularly the delivery of water to the Delta for export, has altered natural flow patterns and ecological processes that maintain habitats in upstream rivers and tributaries and in the Delta. Entrainment also causes direct and indirect mortality to juvenile fish, eggs and larvae.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective is to reduce entrainment of juvenile fish into water diversions in order to increase survival and population abundance to levels that contribute to the overall health of the Delta and other beneficial uses of land and water.

The general target is to reduce the adverse effects of water diversion so that the diversion of water, in conjunction with other restoration actions, does not impair other restoration efforts needed to restore ecological health to the Bay-Delta system.

The following activities would help to achieve this vision:

- Widen the area of concern of the Anadromous Fish Screen Program's multiagency policy level and management team for unscreened diversions which is composed of representatives from the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), U.S. Bureau of Reclamation (Reclamation), DFG, California Department of Water Resources (DWR), and U.S. Natural Resources Conservation Service (NRCS) districts.

- Finish the development of the priority system to install positive-barrier fish screens on all diversions of more than 100 cfs in the upper Sacramento River and all diversions in tributary streams with salmon and steelhead populations by providing funding support to DFG and CVPIA screening programs.

- Construct and test a pilot screening facility in the south Delta adjacent to the Tracy Fish Facility to test a full-sized positive-barrier fish screen and collection system.

- Upgrade the Tracy Fish Facility screens and fish-holding facility and the SWP screens, relocate intakes at screening alternative diversion locations, or modify operations to reduce the time and magnitude of entrainment.

- Support completion of research at the Red Bluff Research Program.

- Assess the effectiveness of test cylindrical screens at DWR siphon diversions on Sherman Island.

- Screen small diversions in Suisun Marsh, focusing on Montezuma and Suisun Sloughs.

- Continue research on fish behavior relative to screening (University of California, Davis Treadmill Study).

- Continue research on fish screening and related facilities design and operations.

- Coordinate research and testing of the various screening programs among resource agencies.

- Develop a long-term screening program plan in cooperation with DFG, USFWS, NMFS, irrigators, and other stakeholders.

- Screen small siphon and pump diversions in the Delta, mainstem rivers, and lower tributaries.

- Develop an incentive plan to encourage local diverters to consolidate smaller diversions where possible to increase the cost-effectiveness of screening.

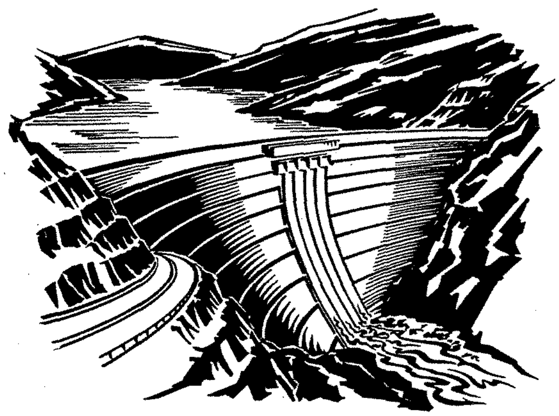
- Consider an upgrade to existing screens at PG&E's Pittsburg power plant and Contra Costa Water District's Mallard Slough diversion with positive-barrier fish screens.

- Provide alternative sources of water to diversions, where possible, in lower portions of tributaries and agricultural lands and managed wetlands along rivers and in the Delta and Suisun Marsh.

REFERENCE

The Resources Agency. 1989. Upper Sacramento River fisheries and riparian habitat management plan. Sacramento, CA.

DAMS, RESERVOIRS, WEIRS, AND OTHER STRUCTURES



INTRODUCTION

Dams, reservoirs, weirs, and other human-made structures come in various forms, from the largest dam (Shasta), to small weirs on tributary streams. Dams stop downstream water flow and capture sediment derived from erosion in the upper watersheds. The captured water backs up to create a reservoir. Seven major dams restrict streamflows from entering the Bay-Delta.

Diversion dams exist throughout the watershed of the Sacramento-San Joaquin rivers and Bay-Delta. Larger weirs are located along the Sacramento River at the Yolo, Sutter, and Sacramento bypasses. Small weirs can be found on most upper watershed tributaries.

Dams, reservoirs, weirs, and other human-made structures act as stressors on ecosystem processes, important habitats, and species in aquatic ecosystems. For example, dams and their associated reservoirs block fish migration, alter water quality, remove fish and wildlife habitat, and alter hydrological and sediment processes. The construction, operation, and maintenance of these structures in the Central Valley have contributed to the decline of many species.

STRESSOR DESCRIPTION

Dams in any form block or hinder upstream and downstream migrations of anadromous fish and hinder downstream transport of sediment. Larger dams completely block anadromous fish migration. These large dams resulted in the loss, and in some cases extinction, of local salmon and steelhead populations (Mills et al. 1996).

Many moderately sized diversion dams, such as Red Bluff Diversion Dam (RBDD) and Anderson-Cottonwood Irrigation District (ACID) Diversion Dam, contain fish ladders to allow fish passage. Some dams, such as Capay Dam on Cache Creek and Solano Dam on Putah Creek, do not.

Small diversion dams are generally constructed to seasonally divert water for irrigation. Although many have been fitted with ladders to allow fish passage, many are technologically outdated and only marginally effective. Often, salmon and steelhead can negotiate the fish ladders, but other species, such as American shad, green sturgeon, and white sturgeon, cannot. In some cases, fish ladders delay adult salmon and steelhead from reaching upstream spawning grounds or downstream migrating juvenile salmon and steelhead.

In high-flow years, water flows from the river into the bypasses and downstream to return to the river or Delta. In such cases, adult salmon and steelhead may migrate upstream through the bypasses and become blocked below the weirs opposite the river. A similar situation occurs in the Sacramento Ship Channel. Blockage and delay of steelhead and winter-run salmon are of particular concern because the fish usually migrate upstream during the winter and spring high-flow periods.

Larger irrigation returns in wetter years have relatively high flows that may attract anadromous fish. Fish attracted to these returns may become lost or delayed. The Colusa Basin drain, which enters the Sacramento River near Knights Landing, is an example of an irrigation return that is known to attract adult salmon.

VISION

The vision for dams, reservoirs, weirs, and other structures is to reduce their adverse effects by improving fish passage and enhancing downstream fish habitat. Reducing these adverse effects will assist in the recovery of State- and federally listed fish species and contribute to sustainable sport and commercial fisheries.

To accomplish this vision, the Ecosystem Restoration Program Plan (ERPP) proposes to address a variety of problems caused by these structures which effect natural processes (e.g., sediment transport), habitats (e.g., riverine and riparian aquatic habitat), and species (e.g., winter-run chinook salmon and steelhead).

For rivers with large dams that block anadromous fish migration, ERPP proposes to improve flow and habitat conditions below these dams. Flow and habitat improvements would enhance salmon and steelhead populations in the lower river reaches. The feasibility of restoring anadromous fish above some of these dams may be considered in the future. Cooperation will be required from local irrigation districts and landowners to rectify these problems.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to reduce the effects of human-made structures on the aquatic ecosystem would involve cooperation and support from other established programs underway to protect and improve conditions for anadromous fish and native resident fishes in the Bay-Delta and its watershed. The recovery plan for the Sacramento/San Joaquin Delta native fishes will be considered in the development of proposed actions (USFWS 1996). CVPIA will implement actions that will reduce adverse effects caused by structures (USFWS 1997). California's Salmon, Steelhead Trout, and Anadromous Fisheries Program Act includes actions to reduce adverse effects of structures (Reynolds et al 1993). The Four Pumps Agreement Program continues to develop projects to reduce effects of structures. Endangered Species Act requirements (biological opinions and habitat conservation plans) will ensure maintenance of existing habitat conditions and implementation of recovery actions (NMFS 1997).

The blockage of migrating anadromous fish in mainstem rivers and tributary streams is a major concern of the Central Valley Project Improvement Act's (CVPIA's) Anadromous Fish Restoration Program (AFRP) and California Department of Fish and Game's (DFG's) Salmon and Steelhead Restoration Program.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Dams, reservoirs, weirs, and other humanmade structures are found throughout the ERPP Study Area and its ecological zones. Large water storage and flood control dams are present on the large rivers and streams and many smaller streams. Water storage and diversion structures impair ecological processes such as Central Valley streamflow, natural sediment supply, stream meander, natural floodplain and flood processes, and Central Valley stream temperatures. This group of stressors also impairs a variety of habitats needed to support fish, wildlife, and plant communities. The most adversely affected habitat is riparian and riverine aquatic habitat. Virtually all fish, wildlife and plant community populations which are dependent on seasonal and perennial aquatic habitats have been reduced. This is particularly true for anadromous fish populations which no longer have access to their former oversummering, spawning, and rearing areas above the major dams.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for dams, reservoirs, weirs, and other human-made structures is to increase the connection of upstream spawning and rearing habitat with the mainstem rivers in the Sacramento-San Joaquin basin in order to increase success of adult spawners and survival of juvenile downstream migrants.

The general target for dams, reservoirs, weirs, and other human-made structures is to reduce or eliminate their adverse influence on ecological processes, habitats, and dependent species.

The following actions would help to restore healthy populations of Central Valley fish:

- Upgrade existing ladder systems to improve fish passage where needed.
- Construct fish ladders, where appropriate, to minimize blockages of upstream migrating anadromous fish behind weirs.
- Provide adequate fish passage, including fish ladders and appropriate attraction flows to the ladders, for small- to moderate-sized diversion dams.
- Where feasible and consistent with other uses, reconstruct diversions or remove dams to allow fish passage.

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USFWS 1997. Revised draft anadromous fish restoration plan: a plan to increase the natural production of anadromous fish in the Central Valley of California. U. S. Fish and Wildlife Service, May 30, 1997 114 p.

USFWS 1996. Recovery plan for the Sacramento/San Joaquin Delta native fishes. U.S. Fish and Wildlife Service, 1996. 195 p.

INTRODUCTION

Three major bypass systems (Butte Basin Overflow, Yolo Bypass, and Sutter Bypass) and more than 2,000 miles of major levees confine floodflow in the Sacramento-San Joaquin Valley tributaries, rivers, and the Bay-Delta.

Levees, bridges, and bank protection structures inhibit overland flow and erosion and depositional processes that develop and maintain floodplains, and allow stream channels to meander. Levees prevent floodflows from entering historic floodplains behind levees, stopping floodplain evolution, and eliminating or altering the character of floodplain habitats. Confining floodflows to channels also increases the fluvial energy that scours or incises channel beds and reduces or halts channel meander and oxbow formation. Bridges have a similar, though generally more localized effect, on channel morphology and sediment transport.

Factors that relate to the degree of influence levees, bridges, and bank protection have on the Bay-Delta include the location and maintenance requirements of these structures.

STRESSOR DESCRIPTION

Levees were constructed in the late 19th and early 20th century to contain the frequent flood flows. Protecting farms, towns, and cities from the devastation of floods drove levee decisions. Another driving force behind levee construction was enhancing river navigation. Thus, levees were placed near riverbanks to increase scour and prevent shoal and bar formation while making the most land available for reclamation. To further improve navigability, a fleet of "snag boats" was employed to remove fallen trees in the channel between the Delta and Red Bluff.

Each section of paired levees, constructed by State and federal projects along major rivers in the valley, is designed to carry a particular flow or flood event. Design flow is determined with the assumption that channel "roughness" (i.e., resistance to flow) will not exceed certain values. Sometimes levees fail even when floodflow is below the maximum design stage, particularly when floodflows have a long duration, such as in January 1997.

Construction materials and standards used to build the early levees would not meet present U.S. Army Corps of Engineers (Corps) structural criteria. Delta levees allowed tidally-influenced emergent marsh to be converted to productive farmland and towns.

In some cases, bank protection has been installed on channelbanks without a levee to protect the landside from erosion inside the river's active floodplain.

In some places, the width of the levees is only a little wider than the width of the channel at low flow, such as along the Sacramento River downstream of Colusa. Restricted channels typically cause deeper, faster velocities during high stage. The amount and width of potential riparian vegetation are restricted by narrow levees, and these river reaches have a low ratio of shallow-water habitats to deep, open water. Cross sections of these channels are typically trapezoidal, rather than a more natural contour with low bank angles and one or more horizontal floodplain surfaces.

Today, most of the Delta levees are higher, steeper, and therefore, pose greater potential risk of failure. This is a result of land subsidence caused primarily by the oxidation, erosion, and depletion of peat soils in the Delta. The former tule islands now resemble steep-sided bowls 5-25 feet below mean sea level.

Extensive areas in San Pablo Bay, Suisun Bay, the Delta, and the Yolo and San Joaquin basins are below mean high tide but are not subject to tidal action because of levees and flapgates. This reduces the area and water volume subject to tidal mixing and reduces the size of the Delta floodplain. Reduced residence time of Delta water and nutrients restricts the development of complex molecules and foodweb organisms. Diked tidelands also may have an artificially high concentration of salt at the surface.

Perimeter Delta floodplains and intertidal zones were formerly punctuated with many miles of low-velocity backwater channels and distributaries. Backwater channels served as nutrient, sediment, and foodweb exchange and delivery systems, as well as important rearing habitat for juvenile fish. At low tides, these branching slough systems provided several miles of mudflat and shallow shoal habitat for shorebirds, wading birds, and waterfowl. Although there are many channels on Delta islands and diked tidelands, they are isolated from the rivers and estuaries by levees. Many have been filled or drained.

Upstream of the Delta, several small and large freshwater tidal sloughs and secondary oxbow channels of the Sacramento and San Joaquin Rivers were once intertwined with main river channels. However, levee construction severed the connections. Some of these former secondary channels are still present as isolated lakes, while others have been filled or drained.

The need for extensive bank protection, primarily rock riprap, has increased because riverbanks have eroded into the narrow floodplains that typically separate levees from channelbanks, highways, railroads, or bridges. In the Delta, riprap is required to protect steep-sided levees from waves caused by wind and boat wakes in wide channels.

Most Delta levees have minimum bank vegetation, and many are covered by rock riprap. Therefore, the riparian corridor is very narrow or absent along Delta channels. In addition, the physical processes necessary to sustain floodplain habitats may be absent or diminished. Riparian vegetation is not allowed to grow on or near most levees further narrowing available habitat area. The aquatic and terrestrial habitat quality of the Delta and river corridor have declined as the percentage of riprapped levee segments increases. Tens of thousands linear feet of riprap are planned for the next phase of the Sacramento River Bank Protection Project.

Bridge spans are often much more narrow than the natural floodplain width, so bridges are usually flood stage "bottlenecks." Backwater effects during high flow may cause channel instability. Additional bank revetment and reduced vegetation are often required so flood flows may safely pass under bridges. At least 31 major bridge crossings exist on the Sacramento River, 10 each across the lower Feather and American Rivers, at least 25 on major Delta sloughs and rivers, and 18 across the lower San Joaquin River to Mossdale.

VISION

The vision for levees, bridges, and bank protection is to reduce the adverse effects of these structures in order to improve riverine and floodplain habitat conditions to assist in the recovery of State- and federally listed fish species, and other fish and wildlife.

Depending on size, location, and type of habitat, setback levees can be used to create high-quality habitat nodes along low-quality, narrow sections of leveed rivers and streams. Much of the interior of central and west Delta islands are at an elevation too low for extensive levee setbacks to be feasible or desirable but should be evaluated on a case-by-case basis. Setback levees may be feasible in the east, north, and south in perimeter Delta areas, Levees set back to higher, firmer ground are more reliable and the setback zone may be available for restored habitats, or farmed part of the year.

In some cases, levees can simply be breached or removed so that the floodplain is setback to the natural shoreline. The soil could be used for restoration elsewhere. Breached-levee areas are prime candidates for restoring networks of small tidal sloughs and shallow backwater channels, increasing habitat complexity and diversity.

Some Delta islands pose overwhelming constraints to agricultural practices and levee and drainage-pump upkeep. Some are candidates for conversion to aquatic and tidal emergent wetland habitats. The Ecosystem Restoration Program Plan recommends a subsidence-control program to gradually restore island elevations.

Actions to control subsidence include:

- managing nontidal emergent and seasonal wetlands to accrete organic island soils.
- filling or raising with clean dredge materials, crop stubble, and soil material, excavated to expand floodway capacity.

Reflooded Delta islands would create a mosaic of interfaced habitat types. Depending on fill available material and island elevations, created habitats should include deep, open-water (greater than 6 feet below mean sea level), shallow-aquatic and nearshore habitats; intertidal mudflats and tule marsh; willow scrub; and mixed riparian forest. Saline areas also support halophytic plant communities such as saltgrass and pickleweed.

Several pilot projects to expand shallow, nearshore habitats along Delta channels using low benches along levees have been constructed and monitored in recent years. These designs will be refined and their application expanded. Other areas of the Delta that have more-than-adequate floodflow capacity could support more vegetation and fill in the channel. Because of the limited width of the area restored and high installation costs of this approach, this measure is considered a lower priority to levee setbacks and removal projects.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to reduce the impacts of levees, bank protection, and bridges will involve coordination with other programs. These include:

- the Upper Sacramento River Fisheries and Riparian Habitat Advisory Council (SB1086) group efforts to limit the placement of rock on banks of the river, and other river corridor management plans;
- the Corps' proposed reevaluation of the Sacramento River Flood Control Project and ongoing Bank Protection Project, including more comprehensive floodplain management and river ecosystem restoration opportunities;
- wetland restoration, under the Delta Flood Protection Act (AB360), such as Decker Island and Sherman Island habitat projects;
- proposed riparian habitat restoration and floodplain management studies, including potential new flood bypass systems and expanded river floodplains on lands recently acquired by the California Department of Parks and Recreation and U.S. Fish and Wildlife Service;
- planned and proposed restoration of diked tidelands of Suisun Marsh and San Pablo Bay and islands in the south Yolo Bypass and Delta; and

- several studies and pilot demonstration projects by the Corps, California Department of Fish and Game, California Department of Water Resources, and others to develop new alternative designs for bank revetment or biotechnical levee protection along rivers and in the Delta that allow for shoreline riparian, marsh, and shallow aquatic habitats.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Levees, bridges and bank protection adversely affect important ecological processes, habitats, and species in the ERPP Study Area. For example, bank protection limits stream channel meander, erosion, reduces opportunity for sediment deposition, and restricts opportunity to regenerate riparian and riverine aquatic habitats. In turn, fish, wildlife, and plant communities are restricted or imperiled.

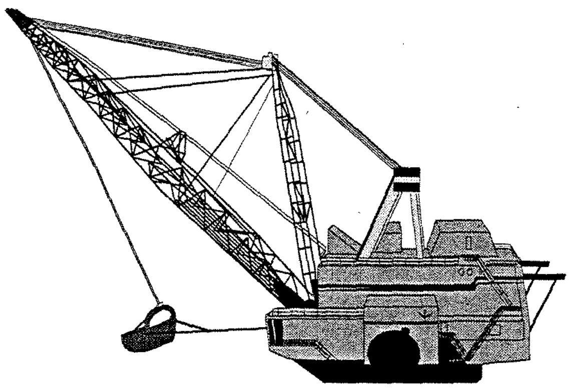
IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for levees, bridges, and bank protection is to reestablish or reactivate geomorphological processes in artificially confined channel reaches to maintain hydrologic connectivity with the natural floodplain.

The general target for levees, bridges, and bank protection is to reduce or eliminate adverse effects on ecological processes, habitats, and dependent species to the extent possible, and in a manner consistent with flood control.

Actions to reduce adverse effects of levees, bridges, and bank protection on the Bay-Delta ecosystem would include the following:

- Investigate the feasibility of levee setbacks along rivers.
- Investigate the feasibility of levee setbacks in the Delta.
- Convert selected Delta islands to a mosaic of deep- and shallow-water and tule-marsh habitats.
- Build innovative benches to support shoreline habitats, where levees must remain.
- Tier from on-going programs to contribute to successful implementation.



INTRODUCTION

Dredging and sediment disposal serves a number of purposes in the Bay-Delta. Most dredging is done to maintain or deepen navigation channels, harbors, and marinas. Dredging is also required to maintain or increase flood control and water conveyance capacity and to obtain material for levee maintenance and repair. This maintenance dredging activity is required because sediments transported to the Delta tend to accumulate in deep channels and backwater areas.

STRESSOR DESCRIPTION

Approximately 2-5 million cubic yards of bottom material must be dredged from the Bay-Delta each year to maintain adequate depth for navigation channels, harbors, and marinas and to maintain flood control and water conveyance capacity. As harbors and channels are deepened to accommodate larger cargo ships, this amount is expected to increase to more than six million cubic yards per year over the next 50 years.

Dredging maintains the Stockton ship channel through the Delta along the San Joaquin River, the Sacramento deepwater ship channel, and the storage capacity in Clifton Court Forebay. Without this maintenance dredging activity, the channels and harbors would become too shallow to accommodate container ships and other heavy vessels. Lack of dredging would also increase the frequency and severity of Delta island flooding. Conveyance of freshwater from the Sacramento River to the southern Delta pumping facilities would also become less efficient.

Dredging and the disposal of dredged material are potentially harmful to the natural productivity of the Bay-Delta ecosystem. The harmful effects of dredging could be a result of the destruction or disruption of benthic communities, turbidity (muddy water) plumes, and release of organics and contaminants from sediments.

Dredge material disposal poses potential environmental problems, particularly when it contains polychlorinated biphenyls (PCBs), elevated concentrations of trace metals, or other potentially harmful constituents. The major effects of increased suspended sediment concentrations (turbidity) at sediment disposal sites are probably on fish behavior, feeding patterns, foraging efficiency, modified prey response, and habitat choice (San Francisco Estuary Project 1993).

Historically, the main disposal sites for dredged material were in the Bay near Alcatraz Island, and offshore in an area that is now within the Gulf of the Farallones National Marine Sanctuary. The Alcatraz disposal site is no longer suitable because it has become a navigation hazard. Disposal is banned in the marine sanctuary. Efforts to identify, evaluate, and prioritize alternative disposal sites are currently underway as part of the LTMS.

Dredging material is needed for agricultural stability and for use in ecosystem restoration. Fill is needed to construct setback levees, reinforce existing levees, and restore wetlands and riparian areas, channel island habitats, and other critical areas. The need for fill will be particularly acute in the lowest-lying Delta islands, some of which are 20 feet or more below sea level. One alternative for restoration efforts in subsided areas would require using fill to stop the oxidation of organic matter in peat soils. Fill material may also be required on islands that are used for continuing agricultural production.

VISION

The vision for dredging and sediment disposal in the Bay-Delta is to maintain adequate channel depth for navigation, flood control, and water conveyance while reducing the adverse effects of dredging activities on the Bay-Delta ecosystem. Dredged material disposal would be environmentally sound and the use of nontoxic dredged material would be promoted as a resource for restoring tidal wetlands and other habitats, reversing Delta island subsidence, and improving dikes and levees.

The ERPP supports the interagency long-term management strategy (LTMS) for dredged materials in the San Francisco Bay and recommends that approximately half of the dredged material from the Bay-Delta be used to restore habitats and strengthen levees. Because one million cubic yards are equivalent to about 620 acre-feet (af), approximately one square mile (640 acres) 3 feet deep can be restored each year. The amount of high-potential tidal wetland restoration sites within the Bay is more than 10,000 acres.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

ERPP supports and seeks to extend the regional approach to dredging and sediment disposal decision making embodied in the LTMS developed by the U.S. Army Corps of Engineers, U.S. Environmental Protection Agency, the San Francisco Bay Regional Water Quality Control Board (RWQCB), the Central Valley RWQCB, and the San Francisco Bay Conservation and Development Commission with the involvement of other agencies and stakeholder groups.

One of the objectives of the LTMS is to promote the reuse of dredged materials whenever it can be shown that there is a need for the material and placement can be done in an environmentally acceptable manner. Restoring tidal wetlands, constructing setback levees, restoring riparian areas and channel islands, and other efforts needed to restore Bay-Delta foodweb productivity and the abundance of fish, waterfowl, and wildlife populations will require fill material. Therefore, there is a great opportunity for linkage between ERPP efforts and managing dredging in the Bay-Delta to the mutual benefit of the ecosystem and the industries dependent on safe and efficient navigation in the Bay-Delta.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

The adverse effects of dredging and the disposal of dredge materials can be adjusted to contribute to restoring ecological health of the Bay-Delta. Dredge materials can be used to recreate shallow water habitats throughout the Delta. This will increase the acreage of this type of habitat and support aquatic and plant species dependent on shallow water habitat.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for dredging and sediment disposal is to reduce loss and degradation of aquatic habitats and vegetated berm islands caused by dredging activities and reduce impacts of dredging activities on aquatic resources during critical spawning and rearing periods and in sensitive areas. Meeting this objective would help to protect, restore, and maintain the health of aquatic resources in and dependent on the Delta.

The general target for dredging and dredge disposal is reduce the loss and degradation of habitat and to contribute sediments for the recreation of shallow water habitats.

The following actions would help to achieve this vision:

- Coordinate all actions closely with federal, State, and local agencies charged with regulating dredging activities in the Bay-Delta.

- Reduce the amount of contaminants flowing into the Bay-Delta and subsequently absorbed by Bay-Delta sediments.

- Identify alternative dredged material disposal sites including upland and ocean sites, to ensure that disposal activities are flexible and avoid undue reliance on a small number of sites.

- Maximize the reuse of dredged materials for habitat restoration and other beneficial uses and minimize the amount of disposed material that is subject to resuspension and subsequent redredging.

- Support continued research on sediment transport and deposition, sediment quality and toxicity testing, the environmental effects of suspended sediment and contaminants, and the beneficial reuse of dredged materials so that dredging and sediment disposal management will continue to improve.

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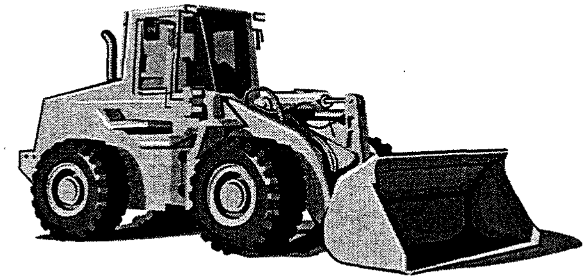

INTRODUCTION

The natural sediment supply of Central Valley rivers and streams is composed of mineral and organic fines, sands, gravel, cobble, and woody debris (e.g., tree branches and root wads), sediments that naturally enter, transport and erode through the system. Sediment is one of the natural building blocks of the ecosystem on which many other ecological processes, functions, habitats and species depend. Gravel, for example, is important for maintaining spawning habitat of salmon and steelhead and supports many invertebrates on which young fish prey. Finer sediments and fluvial (flowing water) processes create conditions necessary to establish new riparian forests and wetlands.

Human activities have had a significant adverse effect on natural sediment processes in the Bay-Delta watershed. One of the more prominent adverse activities is the removal of sand and gravel from active stream channels. Both abandoned and active mining sites exist on virtually every stream or streamside alluvial deposit throughout the ERPP study area (Reynolds et al. 1993).

Sand and gravel mining is a valued commercial activity, but it has impaired sediment transport, gravel recruitment, and stream channel meander processes. Instream gravel extraction damages riparian vegetation, movement of groundwater, water quality, and fish and wildlife populations. In some areas, abandoned gravel pits now harbor predatory fish, serve as heat sinks that increase the ambient water temperature, or capture sediment naturally moving downstream.

STRESSOR DESCRIPTION

Development throughout the Central Valley has increased the demand for aggregate used in construction. Records of the Department of Conservation, Office of Mine Reporting and Reclamation Compliance, show that 1.53 million tons of aggregate were mined in Tehama and Shasta Counties alone in 1992. County and California Department of Fish and Game permits show that up to four million tons could have been mined in the area in 1994, although the actual mined quantity may have been substantially less.

Wide-scale gravel extraction has damaged bridges, siphons, and other river-crossing structures by aggravating degradation and undermining foundations. In Glenn County, for example, the State Route 32 bridge over Stony Creek has been repaired three times at a cost of nearly $2 million. In Tehama County, the Corning Canal siphon is being exposed as the bed degrades, and repairs will cost several million dollars. The North Main Street bridge over Dibble Creek in Red Bluff has been repaired several times at a cost of more than $100,000, and the California Department of Transportation (Caltrans) is concerned about the Interstate 5 bridge over Cottonwood Creek in Shasta County.

Riparian communities are affected by mining in several ways. The most obvious adverse effect is the direct removal or destruction of riparian vegetation by construction of access roads, mined areas, and storage areas. Riparian vegetation can also be lost by degradation and streambank undermining. In addition, degradation and groundwater table reductions destroy shallow-rooted riparian forest for large areas surrounding gravel mines.

Fish are directly affected by gravel removal. Anadromous fish use gravel for spawning. Salmon generally spawn in riffles with water velocities between one and 3 feet per second at a depth of between 0.5 and 3 feet. Mining activities may change riffle velocity and depth or deplete spawning-sized gravel. The Sacramento River and many of the tributaries in the Redding area have been depleted of gravel from a combination of mining and lack of gravel moving downstream from the area above Lake Shasta. In some places, the remaining substrate is too coarse for salmon spawning; in other places, bedrock is exposed over large sections of the stream.

Channel braiding caused by uniform grading during bar excavation can create conditions unsuitable for fish. Higher water temperatures are caused by lower velocities, shallower waters, and reduced vegetation cover of a braided channel. Many fish cannot survive or spawn in higher-than-normal temperatures. These effects may be avoided by maintaining a narrow and deep low-flow channel through a gravel mining area.

Instream gravel mining involves the direct removal of sand, gravel, and cobble from the channel and active floodplain of a stream. Instream mining degrades or eliminates river ecosystem functions, processes, and habitats in the following ways:

- Instream mining homogenizes the geomorphology (shape) of the river channel and its floodplain. Mining removes complex bed forms and elevated floodplains. Channels are typically widened and deepened at mining sites, creating an environment that stops downstream gravel transport. Gravel depletion can accelerate erosion and depletion of several miles of downstream gravel bars. The river will adjust to the reduced bedload by eroding valuable instream bar deposits. Therefore, instream mining causes both direct and indirect downstream loss of gravel and gravel bars.

- Typical extraction rates exceed the average annual yield of gravel from upstream areas. This condition further halts the downstream transport of gravel and often triggers channel incision from the upstream and downstream migration of nick points in the bed elevation as the river compensates for the loss of bedload. Instream mining may cause an increase in the downstream sediment load from fissure sediments dislodged by surface disturbance from mining or channel adjustment. Downstream sedimentation may bury spawning beds in sand and silt or suffocate fish eggs in spawning gravels.

- Instream mining of active channel bars and deep channel deposits is particularly disruptive to the sediment budget of alluvial streams below large dams. This is especially true where there are no major tributaries downstream of the dam to supply another source of gravel and sediment. An example of this condition is the lower American River, where instream and floodplain mining has ceased but where the only significant source of gravel and sediment is from bank and channel erosion below Nimbus Dam. Channel armoring has occurred where bars in the salmon spawning reach are primarily composed of cobbles that resist bed transport at the most common flows. The lower American River and the lower Yuba River are also depleted of fine sediment on bar deposits. There is little support for recruitment of cottonwood seedlings and saplings because these trees cannot germinate or survive in the coarse substrate during summer low-flow conditions.

- Mining removes riparian vegetation, instream woody debris, and spawning redds. All vegetative cover and fluvial landforms must be removed to gain access to the mining site and to clean and sort gravel for commercial use. These habitats may not be replaced until instream mining ceases.

- Deep pit mines excavated in the channel and active floodplain may result in "pit capture." Deep pit mines, such as those prevalent in the tributaries to the San Joaquin River, are often separated by a wall of unexcavated river alluvium. These walls are easily eroded or overtopped by high flows. When this occurs, the river may avulse (move suddenly) from the natural channel into and through the pit, where most gravel bedload will then be captured. When high flows recede, fish will be trapped in the instream "lakes" that are formed. Juvenile salmonids trapped in these lakes are subject to predation and high water temperatures.

- Disturbance from instream mines often leads to the invasion of undesirable non-native plants. Streams with instream mining are often sites with high rates of colonization by invasive non-native plants, such as tamarisk, eucalyptus, giant reed, and pepperweed. These species spread through displaced stem and root fragments or by prolific seed dispersal. For example, channel grading for levee construction and mining on Stony Creek, along with bank erosion, causes giant reed plants to be transported downstream and into the Sacramento River corridor. Once in the corridor, they colonize natural bars and compete with native trees and shrubs. Freshly disturbed and exposed areas at mines also offer prime invasion sites for weedy, opportunistic plant species.

VISION

The vision for gravel mining is to improve gravel transport and cleansing by reducing the adverse effects of instream gravel mining. Achieving this vision would help to maintain or restore flood, floodplain, and streamflow processes that govern gravel supply to improve fish spawning and floodplain habitats.

Opportunities to achieve the vision for gravel mining include reducing or eliminating instream gravel extraction by relocating gravel mining operations to alluvial deposits outside active stream channels and riparian zones and introducing gravel in deficient areas in streams until natural processes are restored to a level that will provide sufficient quantities. The Ecosystem Restoration Program Plan (ERPP) supports channel design or levee construction projects consistent with restoring floodplains to ameliorate this problem.

One strategy to achieve this vision is to identify alternative sources of gravel for fishery restoration and other uses instead of extracting gravel for these purposes from active stream channels.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Programs sponsored by other agencies that would also help to achieve the ERPP vision for gravel mining and recruitment include:

- county-sponsored instream mining and reclamation ordinances and river and stream management plans, such as new gravel and stream management plans approved in Butte and Yolo Counties;

- the State Department of Conservation's reclamation planning assistance programs under the Surface Mining and Reclamation Act;

- Anadromous Fish Restoration Program gravel replenishment programs and plans and small dam removal and/or fish ladder rehabilitation projects (USFWS 1997);

- the San Joaquin River Parkway plan; and
- efforts by the State Department of Conservation and counties to identify alternative sources of commercial sand and gravel in reservoir deltas, floodplain terrace deposits, old dredger mining cobble deposits, and hardrock sites.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Gravel and sand extraction activities adversely effect several important ecological processes, habitats, and the dependent species. Ecological processes include natural sediment supply and stream channel meander. Riparian and riverine aquatic habitat is the most common habitat that is adversely effected by gravel mining. Many fish, wildlife, and plant species are dependent on gravel beds, sediment, and riparian corridors. These are reduced by gravel mining.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective is to reduce the adverse effects of instream gravel mining to improve gravel recruitment, cleansing, and transport processes, contribute to natural stream sediment supply, and improve other stream channel processes.

The general target for gravel mining is work with local counties and the aggregate resource industry to relocate gravel extraction operations to areas outside the active stream channel.

Three actions to reducing the adverse effects of gravel mining include the following:

- Promote alternative gravel sources. ERPP recommends providing education and other incentives to encourage counties and mining companies to seek new off-channel sources of aggregates, including high terraces outside the active floodplain, recycled concrete, crushed cobbles from old abandoned dredge spoils, and deep pit mines away from river migration corridors. New permits for these aggregate sources can be issued in exchange for phasing out instream mines.
- Limit the extent of disturbance at instream mines. If alternative sources of aggregate are not a viable short-term solution, permits should require an undisturbed corridor of riparian vegetation and natural bar deposits adjacent to existing mines. In addition, extraction rates should be limited to the estimated yield from upstream each year. This rate will vary annually and must be verified by aerial topographic analysis or field surveys at permanent transects.
- Prevent or reduce the effects of pit capture. Deep pits should be adequately separated from the channel and measures should be taken to ensure that bank material and vegetation will resist channel migration in the direction of the pits. Alternatively, permits should require that inchannel pits be filled with overburden to the elevation of the channelbed.

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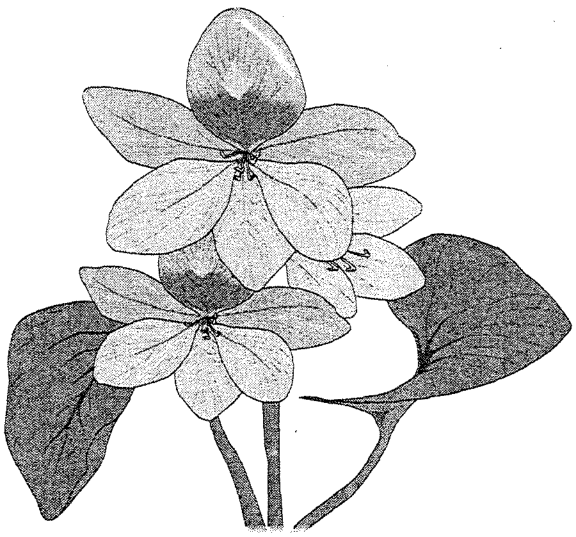

INTRODUCTION

Weeds, or invasive plant species, are types of vegetation capable of exploiting opportunities afforded by natural or human-related disturbances in the landscape, as well as those provided by relatively undisturbed habitats. Although not all weeds are non-native, most have been introduced from other parts of the world.

Invasive aquatic plants have become sufficiently established in some locations to threaten the health of the Bay-Delta ecosystem. The aquatic plants that pose the greatest threats to aquatic ecosystems are those that directly or indirectly affect rare native species, decrease foodweb productivity, and reduce populations of desired fish and wildlife species.

Factors that relate to the degree of influence invasive aquatic plants have on the Bay-Delta include additional introductions from ship ballast and other sources and local water quality and hydrologic conditions that favor their establishment.

STRESSOR DESCRIPTION

Lacking the controls found in their native habitat (e.g., specific insects for which they are a food source or toxins produced by competing plants), these plants can flourish in a new landscape, gaining a competitive advantage over the native species. Many weeds have evolved characteristics that make them extraordinarily competitive in both natural and introduced environments, such as high seed production; mechanisms for effective seed dispersal; rapid growth rate; and adaptability to extremes in temperature, nutrients, and water availability.

A species is considered a weed problem because of its ability to adversely affect natural communities or human land use requirements. Introduced or native aquatic plant species are considered harmful when they reduce the biological diversity of existing natural communities by displacing native species or altering ecosystem processes such as nutrient cycling, hydrologic conditions, or water chemistry. They create problems for human society when they impair agricultural or aquacultural productivity, constrict waterways, diminish recreation and aesthetic values, or destroy structures.

Most aquatic weeds were introduced to California waterways unintentionally. They were brought in as pond ornamentals (e.g., water hyacinth) and aquarium plants (e.g., hydrilla), or through dispersal by boats. Aquatic weeds have been here for at least 100 years; water hyacinth was discovered in a Yolo County slough in 1904. Hydrilla, which was probably introduced through its use as an aquarium plant, has been in California for at least 20 years. Egeria, still a popular aquarium plant, has been in the ecosystem for over 30 years.

Most aquatic weeds pose a threat to the aquatic foodweb and rare aquatic or riparian species because they form dense mats that block sunlight or deplete oxygen supplies. The sheer mass of floating tissue can also impede navigation and damage water control structures. Establishment of invasive aquatic plants can harm or kill rare and valued fish, native plants, and other aquatic organisms; reduce biodiversity; impede navigation; damage water control structures; and increase mosquito habitat.

Many stream and river channels in the Delta and the Sacramento and San Joaquin Rivers and their tributaries have been channelized, confined by levees, impounded, and otherwise altered from their shapes of 150 years ago. With the conversion of adjacent riparian communities to other land uses, the ecosystem processes and functions have changed substantially. These changes stress native aquatic flora and fauna, leading to changes in species composition and population densities, and perhaps making the aquatic foodweb more vulnerable to further stressors.

Most weeds that infest the Delta and the Sacramento and San Joaquin Rivers and their tributaries are problems in specific locations, not throughout these waterways; however, locations of aquatic weeds have not been comprehensively mapped. The California Department of Food and Agriculture's Integrated Pest Control Branch records locations where aquatic weeds, such as hydrilla, pose a threat to agriculture. Locations of weeds that threaten natural areas are not recorded. Comprehensive mapping throughout the ERPP study area is needed for all weeds that threaten aquatic habitat as a first step to monitoring and controlling infestations.

Some non-native aquatic weeds that pose the most serious threats and need further research, monitoring and mapping, or control are egeria, hydrilla, water hyacinth, water pennywort, eurasian watermilfoil and parrot feather. Each of these is described below. These weeds flourish in a wide geographic area, sometimes in high densities, and are extremely dangerous because of their ability to displace native plant species, harm fish and wildlife, reduce foodweb productivity, or interfere with water conveyance and flood control systems.

Egeria (*Egeria densa;* syn: *Elodea densa*): A native of South America, egeria is a popular aquarium plant, which most likely accounts for its introduction into California waterways. It is a submerged, rooted perennial that occupies the same littoral zone niche in slow-moving water as native pondweeds, thereby potentially excluding the pondweeds and reducing the habitat value for waterfowl that eat pondweeds. Egeria creates a structure having much more branching than pondweeds. It forms dense mats that block sunlight and reduce the amount of open water, leading to increased accretion of organic material and increased sedimentation. The dense mat structures may impede diving waterfowl from foraging, and the increased sedimentation may alter the population of benthic species and their predators.

Egeria has been in the Delta for perhaps 30 years or more but probably was not a major problem until the past 12 years, coinciding with the water hyacinth control program. Removing water hyacinth from waterways and a 6-year drought may have contributed to the expansion of coverage by egeria (Anderson pers. comm.).

Egeria currently infests approximately 3,000 acres, primarily in the Delta. The success of this infestation in the Delta is indicative of the greater success that hydrilla would have if it were not prevented from establishing there. Hydrilla, unlike egeria, has long-lived rhizomes, making it much more difficult to control. Egeria is listed as a "B"-rated noxious weed by the California Department of Food and Agriculture's Noxious Weed Program. This designation does not mandate its control and, because the species is so widespread, little attention has been paid to controlling it. Now that growing populations are increasingly obstructing water conveyance structures and natural wetlands, the California

Department of Boating and Waterways is given $500,000 per year to control egeria along with water hyacinth (Anderson pers. comm.). Returning native pondweeds to an egeria-infested site would probably require active restoration once the egeria is removed.

Hydrilla (*Hydrilla verticillata*): A submerged perennial, hydrilla was introduced to North American waterways sometime after 1956 through its use as an aquarium plant. It has since spread throughout the country, infesting waterways, irrigation canals, lakes, and ponds. It can completely fill and clog waterways, restricting flow, increasing sedimentation, and hindering navigation and public water use. Like egeria, hydrilla forms dense mats that block light, deplete oxygen, and increase sedimentation and organic deposition. In slow-moving water and oxbows, hydrilla can deplete oxygen and resources to the point of causing fish kills. Unlike egeria, however, hydrilla forms rhizomes that live 5-7 years and from which new plants can grow. Because of the persistence of rhizome viability, hydrilla will be much more difficult to remove from the Delta, if it establishes there, than egeria.

Hydrilla is an "A"-rated weed in the California Department of Food and Agriculture's Noxious Weed Program. This designation means that the plant poses a serious problem to agriculture but may be contained through control efforts. Since 1976, when it was first noticed, the California Department of Food and Agriculture has spent $20 million to eradicate hydrilla (California Exotic Pest Plant Council Biocontrol Committee 1995). Hydrilla has been found in 17 counties in California and has been eradicated from nine counties. Thus far, it has been prevented from establishing in the Delta. An example of its invasiveness can be seen in Clear Lake in northern California, where it now covers about 650 acres of the lake's 43,000-acre surface area.

Water hyacinth (*Eichhornia crassipes*): A floating perennial, water hyacinth is native to South America. It infests streams, ponds, backwater areas, ditches, sloughs, and waterways. It grows rapidly in the summer, floating and spreading by means of buoyant stolons and seed. Water hyacinth was introduced to the United States in 1884 when it was given to visitors as souvenirs at the Cotton States Exposition. Water hyacinth was first reported in California in a Yolo County slough in 1904. Today, it is a serious pest in the Delta, the Sacramento and San Joaquin Rivers, and many sloughs and tributaries, where it clogs waterways, obstructs commercial and recreational navigation, and impedes water conveyance.

Water hyacinth is also a serious problem for the pumping and fish-screening facilities in the south Delta. Forming a dense cover over the water surface, it blocks sunlight, reduces water flow, depletes oxygen, and inhibits gaseous interchange with the air, all of which harm other aquatic organisms. Water hyacinth increases mosquito habitat by providing larval breeding sites where mosquito predators cannot reach. In backwater areas, dense concentrations of water hyacinth can increase fish mortality. It also increases sedimentation and the accretion of organic matter. Water hyacinth reportedly competes with Mason's lilaeopsis (*Lilaeopsis masonii*), an endangered freshwater emergent plant native to California (Van Ways pers. comm.).

In 1982, the California Department of Boating and Waterways formed a task force to begin controlling water hyacinth, testing different mechanical and herbicidal control methods. In 1996, the department spent $900,000 to treat 1,750 acres of water hyacinth, mostly in the central and southern Delta (Van Ways pers. comm.). Some control efforts involve aerial spraying of herbicides, but in many areas herbicides must be applied from boats. Since water hyacinth control began, egeria populations have expanded. Egeria clogs boat propellers quickly and has made continued control of water hyacinth much more difficult. As a result, the department has now been given approval and funding to control both egeria and water hyacinth.

Water pennywort (*Hydrocotyle umbellata*): A perennial native plant, water pennywort grows along streambanks and in ponds, canals, and marshy areas. It forms stems that float and creep along wet soil. Although it takes root, plants also break off and form dense, floating rafts that drift. These rafts can cause some of the same problems seen with water hyacinth. Since water hyacinth has been controlled, the pennywort population has increased and become a weed problem in some areas. (Anderson pers. comm.).

Eurasian watermilfoil (*Myriophyllum spicatum*) and parrotfeather (*Myriophyllum aquaticum*): Both Eurasian watermilfoil and parrotfeather are submerged perennials. Eurasian watermilfoil, as its name suggests, is native to Eurasia; parrotfeather is native to South America. Parrotfeather is sold in nurseries for aquariums and backyard ponds. Eurasian milfoil is much more abundant statewide than parrotfeather; however, no comprehensive surveys have measured the extent of these two weeds. Because Eurasian milfoil has not created a specific problem for agriculture, it has not been targeted for control. An example of a Eurasian milfoil infestation is in Lake Tahoe, where it covers about 200 surface acres, mostly in the marina area. Parrotfeather is found in seasonally wet streams, small lakes, and flood control channels. An example of its infestation is found in Parks Lake on Beale Air Force Base.

Like hydrilla and egeria, both of these plants occupy areas where native pondweeds would grow. Eurasian milfoil grows mostly submerged, whereas parrotfeather extends above the water. The growth form of parrotfeather results in substantial increases in mosquito habitat. Although both plants may present problems, they can be beneficial to aquatic habitat as well. Parrotfeather is thought to provide cover for aquatic organisms, and Eurasian milfoil stems and fruits are eaten by waterfowl (Westerdahl and Getsinger 1988).

VISION

The vision for invasive aquatic plants is to reduce their adverse effects on native species and ecological processes, water quality and conveyance systems, and major rivers and their tributaries.

Active management of Delta streams and rivers is necessary to reduce the surface area of channels and sloughs in the Delta that are covered by water hyacinth and other invasive aquatic plant species. To effectively control aquatic weeds, existing programs will need to be expanded and funded or new programs created. Currently, locations for hydrilla and noxious weeds that pose a threat to agriculture are reported as part of the California Department of Food and Agriculture's Integrated Pest Control Program; however, weeds posing a threat to natural habitats are not mapped. An improved mapping and monitoring program that efficiently maps and monitors all targeted weeds will aid in their control, especially for rapidly spreading species. Such a program will also help to assess changes in the population levels and the effectiveness of control programs. Expanding California's noxious weed program to include weeds that pose a threat to native species or habitats would also aid in building an effective long-term aquatic weed control program.

To facilitate effective control programs for these species, all groups involved must coordinate with one another to control and restore habitat in Delta waterways. A coordinated approach to eliminate all damaging weeds, rather than only selected weed species, can reduce instances where one weed infestation replaces another, as exemplified by the increases in egeria and pennywort populations following efforts to control water hyacinth. In addition, regulatory agencies and those obligated to implement control programs must coordinate their efforts to plan and implement those programs that are appropriate to meet the specific needs of each site. Because the ecological, recreational, water quality, water conveyance, and commercial needs vary at each site, a general control strategy or regulatory policy is not possible. The specific needs of a site must be assessed and the costs and risks of different control strategies must be compared to determine the most appropriate strategy for each site. As a result, some sites will require more restrictive strategies than others.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

The California Department of Food and Agriculture's Integrated Pest Control Branch tracks and controls federally listed noxious weeds throughout the State. These are weeds that have an impact on agriculture, although most of the current infestations are restricted to natural and uncultivated areas. Listed weeds are given a letter designation: "A" weeds are tracked and targeted for control or eradication wherever they are found; "B" weeds are considered too widespread to require mandated control of them, and the decision to control them is left to the county agricultural commissioners; "C" weeds are so widespread that the agency does not endorse State- or county-funded eradication or control efforts except in nurseries and seed lots.

Of the weeds described in this vision statement, only hydrilla is listed as a noxious weed. With funding, the California Department of Food and Agriculture's Integrated Pest Control Branch could be expanded to include weeds that adversely affect natural areas and their existing infrastructure and the expertise of that branch could be used to track, map, and control weeds that pose problems in natural areas.

Two recently announced programs or policy changes may have a beneficial effect on the vision for controlling invasive non-native aquatic and riparian weeds. The first is a new weed policy developed by the U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) that regulates not only weeds that threaten agricultural or managed areas, but those affecting natural areas as well. This program will use a risk assessment to identify weeds federally listed as noxious. Among other aspects of the new policy, APHIS will have a regulatory role, detecting, assessing, and containing incipient infestations. The policy states that APHIS will act in a federal coordination role to facilitate communication and cooperation among relevant public agencies and others (Westbrooks 1995).

The second new approach was formed through a Memorandum of Understanding (MOU) signed in 1994 by 17 land-holding federal agencies. The Federal Interagency Committee for Management of Noxious and Exotic Weeds was formed, under the MOU, to enable the signing agencies to cooperatively manage noxious and non-native weeds on federal lands and to provide technical assistance on private land to achieve sustainable, healthy ecosystems that meet the needs of the society (Jackson 1995).

Many other organizations have weed issues in the Delta, all with different roles, interests, and expertise. Implementing the ERPP vision requires a coordinated effort among these groups to develop and implement weed management programs and strategies that will help meet ERPP's goals for the various resources and ecological zones.

- The U.S. Department of Agriculture - Agricultural Research Service Aquatic Weed Control Research Laboratory in the Department of Vegetable Crops at the University of California at Davis conducts ongoing research on aquatic weed control.
- The California Weed Science Society is a 50-year-old organization serving the weed science community.
- The California Exotic Pest Plant Council is a nonprofit organization that focuses on issues regarding non-native pests and their control and educates the public on these issues.

- The U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S. Bureau of Reclamation, California Department of Fish and Game, State Water Resources Control Board, Central Valley Regional Water Quality Control Board, California Department of Food and Agriculture, and California Department of Health Services have regulatory or programmatic roles pertaining to aquatic weed control in the Delta and the Sacramento and San Joaquin Rivers and their tributaries.

In addition to these, several public and private groups deal directly or indirectly with aquatic weeds in the Delta. Among them are:

- California Native Plant Society,
- The Nature Conservancy,
- the State and national parks systems, county and local parks departments,
- Animal and Plant Health Inspection Service ,
- U.S. Army Corps of Engineers,
- U.S. National Resources Conservation Services,
- Center for Natural Lands Management,
- resource conservation districts, mosquito abatement districts, flood control districts,
- California Association of Nurserymen,
- local land trusts,
- and private landowners.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Invasive aquatic plants adversely influence other ecosystem elements including ecological processes, habitats, and species. For example, introduced species have outcompeted and displaced many native species. The proliferation of exotic plants has impaired the proper functioning of fish protective devices such as fish screens and fish louvers in the Delta.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for invasive aquatic plants is to reduce the adverse effects of these species on native plants to increase and maintain the productivity of the aquatic foodweb, preserve suitable fish habitat structure, and provide quality habitat conditions for native submergent and emergent plants.

A comprehensive strategy to reduce invasive aquatic plants and their adverse effects on the Bay-Delta ecosystem would include the following items.

- Assess aquatic weeds for their level of threat, their extent, and their potential to be controlled in the long run.
- Assess potential weed control sites to determine how effective control efforts will be in improving habitat quality, the longevity of results, and the sites' likelihood of providing the types of habitats and habitat characteristics proposed for restoration.
- Develop and implement management plans to achieve specific targets for each weed and site.

- Implement habitat restoration (e.g., planting native pondweeds and other desirable aquatic and emergent wetland plants) concurrent with or following implementation of control measures, where appropriate.

- Eradicate water hyacinth from major tributaries and marinas, locks, important wetland areas, and wildlife refuges in the Sacramento-San Joaquin Delta Ecological Zone.

- Elsewhere, reduce the biomass of infested acreage to a lower maintenance level than of the present summer cover. This goal would be approached beginning in the tributaries entering the Delta, and aiming for total eradication there; then water hyacinth will be contained at maintenance levels in upstream locations.

- Provide technical expertise, serve as a clearinghouse for regional information and project results, and assist with implementation of high-priority local projects in specific ecological units or zones to increase the effectiveness of existing public and private programs to reduce the threat of invasive species.

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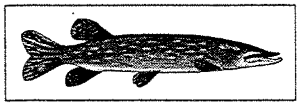
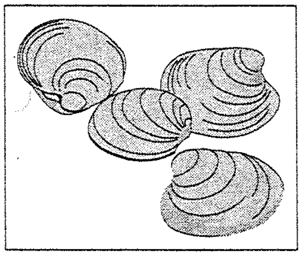


Northern Pike



Asian Clams

INTRODUCTION

Most of the clams, worms and other bottom-dwelling invertebrates presently inhabiting the Bay-Delta are introduced from other estuaries. Non-native species also make up an increasing proportion of the zooplankton and fish communities of the Bay-Delta. It is estimated that a new non-native species is identified in the Bay-Delta every 15 weeks.

Many species were transported on the hulls of ships or in ship ballast water. Others arrived with the Atlantic or Japanese oysters purposely introduced into the estuary earlier in this century. Many fish, including striped bass, American shad, and largemouth bass, were introduced by federal and State resource agencies to provide sport fishing or forage fish to feed sport fish. Others, such as the northern pike, in a western Sierra reservoir, were purposely and illegally introduced.

Whether accidental or intentional, the introductions of these organisms have greatly increased the species diversity of the Bay-Delta aquatic community. However, this increase in diversity has occurred at the expense of native species, some of which have declined precipitously or even become extinct because of predation and competition from non-natives. Some introduced species are nuisances because they attach to boat hulls, bore into dock pilings, clog drainage pipes, tunnel into levees, or compete with or prey on valuable native species. Many non-native species, however, perform vital ecological functions such as serving as primary consumers of organic matter, or as a food source for Bay-Delta fish, shorebird, waterfowl, and other wildlife populations. Many non-native species have invaded the Bay-Delta successfully by filling new habitat niches that previously did not exist. Restoration of natural habitats with more natural flow regimes and hydraulic conditions throughout the Bay-Delta will hopefully favor native species. Continued study of the effects of non-native species on the abundance and distribution of native species and on the rest of the Bay-Delta ecosystem will be part of the adaptive management program guiding these restoration efforts.

STRESSOR DESCRIPTION

Invasive aquatic organisms are those non-native fish and invertebrates that have invaded the Bay-Delta at the expense of native species. Non-native aquatic invertebrates of the Bay-Delta include a wide variety of sponges, coelenterates, worms, molluscs, and crustaceans. Most are bottom-dwelling organisms as adults, but some planktonic forms have also become well established, especially in the last few years. Most were introduced accidentally from the hulls of ships passing through or abandoned or sunk in the Bay-Delta, from the release of ship ballast water, and from oysters (which usually contain dozens of nestling, symbiotic and parasitic invertebrates) brought in from Japan and the Atlantic coast for aquacultural purposes.

The first recorded introduced species, the Atlantic barnacle (*Balanus improvisus*) was observed in 1853, the single busiest year of clipper ship landings of the Gold Rush era. Since then, many species of non-native fish and invertebrates have been introduced into the estuary. The success of these introduced species is due in part to the comparatively small number of native species thought to have been present during aboriginal times and in part to environmental modifications to which non-native species were often preadapted.

The relatively low native-species diversity is thought to be a result of the relatively young age of the Bay-Delta estuary and its isolation from other Pacific Coast estuarine systems (Carlton 1979). Important environmental changes that most likely decreased native species' ability to compete with non-native species include changes in Bay-Delta morphometry, vegetation, hydraulics, and the amount and timing of Delta outflow.

It is not clear to what extent the decline in abundance of some native species is a result of environmental changes or to interactions with non-native species. It is known, however, that non-native species now figure prominently in the diets of fish species, shorebird and invertebrate-eating waterfowl, and other wildlife species. Most non-native fish and invertebrates perform a vital role in the Bay-Delta foodweb. Certain species, however, have become so abundant in some areas or have been shown to exert a negative effect on ecosystem health or economics in other areas that their mere presence in the Bay-Delta is a source of considerable concern.

The Asian clam, *Potamocorbula amurensis,* was first observed in 1986 and has since become extremely abundant in the Bay and western Delta. This species is well adapted to the Bay-Delta saltwater conditions and exerts a heavy grazing loss on phytoplankton and zooplankton in the Bay. Precisely how the Asian clam is affecting other benthic invertebrates, the zooplankton abundance and composition, or the larval and young fish health is still not well understood, but is thought to be generally detrimental. This is especially true for native species. On the positive side, Asian clams may contribute to the foodweb as an important food source for white sturgeon (Peterson 1997).

The zebra mussel, *Dreissena polymorpha,* another clam-like species many believe will soon invade the Bay-Delta, poses a similar ominous threat.

The Asian clams came on the heels of another clam invasion. *Corbicula manillensis* was also introduced from Asia. It was first described in the Delta in 1946. This clam does not tolerate saline waters. It is now very abundant in freshwater portions of the Delta and in the lower mainstem rivers adjacent to the Delta.

Another relatively new arrival to the Bay-Delta is another species from the Orient, the Chinese mitten crab (*Eriocheir sinensis*). This crab spends most of its life in fresh water and migrates downstream to spawn in salt water. Mitten crabs were first captured in south-Bay shrimp trawls in 1993. Their distribution and abundance have increased every year since then (Hieb 1997). Although these crabs may have an adverse effect on the red swamp crayfish (another non-native species), its greatest potential negative impact on the Bay-Delta may be its effect on levees. Mitten crabs dig burrows in clay-rich soils where banks are steep and lined with vegetation. These burrows accelerate bank erosion and slumping and, over time, may pose a serious threat to Delta levee integrity. The crabs also interfere with bay shrimp fishing by fouling nets.

Introduced zooplankton species have become important elements of the Bay-Delta. *Eurytemora affinis* was probably introduced with striped bass around 1880. Until recently, it was a dominant calanoid copepod of the entrapment zone. In the last decade, however, Eurytemora has been replaced by two calanoid copepods introduced from China. This replacement was a result, in part, of Eurytemora's greater vulnerability to Asian Clam grazing.

The native mysid shrimp, *Neomysis mercedis,* began dwindling in abundance in the late 1970s primarily as a result of the declining trophic status of the Bay-Delta. Its population decline was also affected by competition with *Acanthomysis aspera*, an introduced mysid shrimp of somewhat smaller size but similar feeding habits.

Although many non-native fish species have been introduced to the Bay-Delta over the past century, only a few have been considered invasive and requiring control. The most recent example is the northern pike introduced into Davis Lake, a State Water Project reservoir on the Feather River. Two unconfirmed sightings of northern pike occurred in the Delta in early 1997. Northern pike are noted predators and could, if allowed to establish themselves, pose a significant threat to native fishes, such as chinook salmon, steelhead, and delta smelt. White bass were a similar threat in the 1980s; however, a concerted effort ensured they did not move from isolated southern San Joaquin Valley reservoirs into the San Joaquin River.

VISION

The vision for invasive aquatic organisms is to reduce their adverse effects on the foodweb and on native species resulting from competition for food and habitat and direct predation. This vision can be accomplished through enforcement of Federal laws regulating ballast water dumping and other measures designed to reduce the number of new, potentially harmful species introduced accidentally into the Bay-Delta estuary. Habitat changes or direct control measures may reduce their effects in specific cases.

The introduction of non-native species to the Bay-Delta has been a mixed blessing. Most have successfully integrated into the Bay-Delta aquatic community. Others, however, have hastened the extinction or greatly reduced the abundance of native species or have become an economic nuisance. Once established, non-native species cannot be effectively removed by harvesting or poisoning, except perhaps in small localized areas.

The only practical way to minimize the spread of non-native species and promote the growth of native species is to restore the habitats to more natural conditions. Restoring more natural, native aquatic communities should promote greater ecosystem stability by reducing the likelihood of catastrophic reductions in abundance of native organisms resulting from changes in environmental conditions.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to restore the natural environmental conditions, trophic status and native invertebrate community of the Bay-Delta will involve the cooperation and support of established programs underway to restore habitat and fish populations in the basin.

- Restoration of the plankton food supply of native fishes is a primary focus of the Recovery Plan for the Sacramento/San Joaquin Delta Native Fishes (U.S. Fish and Wildlife Service 1995).
- The Central Valley Project Improvement Act (CVPIA) calls for the doubling of the anadromous fish populations (including striped bass, salmon, steelhead, sturgeon, and American shad) by 2002, through changes in flows and project facilities and operations. This program involves actions that may directly or indirectly benefit native invertebrates of the Bay-Delta foodweb.
- The California Department of Fish and Game is required under State legislation (The Salmon, Steelhead Trout, and Anadromous Fisheries Program Act of 1988) to restore numbers of anadromous fish in the Central Valley. Actions include restoring the food supply of anadromous fish.

- Efforts will be coordinated by the State Water Resources Control Board and Regional Water Quality Control Boards to reduce the amount of toxic substances released into Central Valley waterways, which should help reduce stresses on the native and non-native invertebrate species.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Invasive aquatic organisms adversely influence other ecosystem elements including ecological processes, habitats, and species. For example, introduced species have outcompeted and displaced many native species. The proliferation of these exotic organisms has altered the Bay-Delta foodweb.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for invasive non-native aquatic invertebrates is to reduce introductions of non-native species in order to protect and provide sustainable populations of native species.

The general target for invasive aquatic organisms is control and reduce the incidence of introductions and to implement control programs or eradicate exotic species where possible.

Actions that would help achieve this vision include more stringent enforcement of current policies regarding the introduction of non-native species. These policies seek to prevent the introduction of known noxious species and minimize the introduction of all other species. In addition to prohibiting intentional introductions, enforcing existing laws such as International Maritime Organization's Guidelines will reduce the number of accidental introductions from ship ballast water.

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INTRODUCTION

Invasive riparian and salt marsh plants have become sufficiently established in some locations to threaten the health of the Bay-Delta ecosystem. The riparian and salt marsh plants that pose the greatest threats to aquatic ecosystems are those that directly or indirectly affect rare native species, decrease foodweb productivity, and reduce populations of desired fish and wildlife species.

Factors that relate to the degree of influence invasive riparian and salt marsh plants have on the Bay-Delta include additional introductions from gardens and other sources, and ground disturbances and hydrologic regimes that create favorable conditions for their establishment.

STRESSOR DESCRIPTION

Weeds, or invasive plant species, are organisms capable of invading relatively undisturbed habitats and exploiting opportunities provided by natural or human-related disturbances in the landscape. Although not all weeds are non-native, most have been introduced from other parts of the world. In the absence of the natural biological controls found in their native habitats, such as herbivory by specific insects, weeds can flourish with fewer constraints in a new landscape, quickly gaining a competitive advantage over the native species. Many weeds have also evolved characteristics that make them extraordinarily competitive in both native and non-native environments. These specialized traits may include high seed production, both sexual and asexual reproduction, several methods of dispersal, a fast growth rate, and tolerance of a wide range of environmental conditions such as extremes in temperature, nutrients, and water availability.

A plant species becomes a weed problem when it adversely affects natural communities or land uses. Whether non-native or native, plant species are considered harmful when they reduce the biological diversity of existing natural communities by displacing native species or altering ecosystem processes such as nutrient cycling, hydrologic conditions, or the frequency of fires. They are problems to human society when they impair agricultural productivity, present fire hazards, constrict waterways, diminish recreation and aesthetic value, or destroy structures.

Since the first non-native settlers, weeds have been introduced to California and many have become established. There were at least 16 non-native plant species established by 1869, 292 by 1925, 797 by 1968, and 1,023 by 1993 (Barbour et al. 1993). Undoubtedly, non-native species introductions will continue, and correspondingly, add pressure on the native plant communities and the wildlife that depend on them.

More than 90% of the State's historic riparian habitat has been lost, primarily as a consequence of land being converted for agricultural uses (Barbour et al. 1993). What remains continues to be threatened, not only by further habitat conversions, but also by weeds. It is particularly important for the many endangered and threatened species that weeds are controlled, particularly for birds and fish that depend on native riparian plant communities.

Many riparian infestations are from species, such as Pampas grass, that spread from gardens. Others were planted intentionally along engineered or altered waterways for erosion control or in the belief that native vegetation would be too vigorous and would clog waterways (Dawson 1984). Weed infestations in riparian and salt marsh systems are magnified by both alterations to the landscape and current land use patterns. Clearing land allows weeds that thrive in disturbed areas, such as ailanthus, to invade bare areas and move into established forests. Overgrazing in riparian areas can diminish recruitment of new native trees and shrubs directly and indirectly by contributing to the establishment of a dense understory of non-native vegetation that hinders native seedling establishment. Some orchards may be a source of riparian weed infestations, as may have happened with the establishment of California black walnut, used as rootstock in English walnut orchards.

Urban development adjacent to riparian areas can lead to infestations by ornamental garden plants such as German ivy, arundo or giant reed, elm, black locust, and edible fig. Increases in summer ground and surface water from irrigation can harm some riparian vegetation, altering the species composition. It can create conditions leading to a higher rate of invasion by urban area weeds such as Bermuda grass that can compete with native seedlings, thus affecting forest regeneration. Left alone, many weeds can take over part or all of the established riparian or salt marsh communities, displacing the native vegetation and becoming the new climax successional species. Examples include arundo and tamarisk. Both were intentionally introduced and now are widespread weeds that have displaced extensive areas of native riparian vegetation throughout the western United States.

Most Central Valley and Delta riparian communities are confined to lower floodplain and river channel areas, compared to a much wider distribution over vast floodplains 150 years ago. With the conversion of riparian communities to other land uses, broad outer bands of riparian vegetation were lost or their extent greatly diminished, like those dominated by sycamores.

Today, most watercourses are confined to narrower channels with little room for changing patterns of braiding and migration. Inundation and sedimentation rates are altered from historical times in river channels and are substantially reduced in floodplain areas. In the Delta, sedimentation is also altered with the erosion of islands.

Habitat losses or alterations have resulted in a pattern of habitat fragmentation. Riparian communities are often disconnected patches along river channels, and salt marshes are either newly developed from sediment deposition or smaller patches of formerly great expanses. The alteration of ecosystem processes like sedimentation, nutrient flow, fire, and hydrologic conditions, along with reduction in cover and native plant community diversity, has resulted in degraded riparian or salt marsh habitat conditions. The riparian or salt marsh community is then vulnerable to invasions by non-native species that are better adapted to the altered conditions than the native vegetation.

Species such as arundo and tamarisk are able to quickly exploit disturbed riparian sites. They, in turn, alter the ecosystem processes further, changing the frequency of fires, increasing shade and sediment capture, armoring the streambed and banks, altering soil salinity (tamarisk), and modifying the hydrologic patterns. The native species are not adapted to the new ecosystem processes, and the introduced weeds dominate the successional community.

Weeds that pose the greatest threats to riparian and salt marsh areas are those that outcompete and exclude native vegetation and diminish habitat value to wildlife and reduce biodiversity of native species. All weeds listed in the following section have this potential.

Numerous weeds threaten the establishment and succession of native riparian and salt marsh vegetation in the Delta and along the Sacramento and San Joaquin Rivers and their tributaries. Some of the most invasive, listed below, include weeds that are widespread, often extensive, and extremely dangerous because of their ability to dominate riparian or salt marsh communities and affect ecosystem processes (arundo and tamarisk). Other invaders are trees or shrubs that now dominate portions of riparian forests and can invade larger areas if not controlled (ailanthus, edible fig, northern California black walnut, eucalyptus, black locust, and Russian olive). Additional examples include some weeds that are primarily a problem in a more restricted range or ecological zone type (perennial pepperweed, German ivy, cordgrass, and purple loosestrife).

Both arundo and tamarisk are widespread weeds capable of causing enormous damage to California riparian communities. They reduce biological diversity, habitat value for wildlife, and ecosystem processes such as flooding patterns and fire frequency.

Arundo (*Arundo donax*), also known as giant reed or false bamboo: Native to the Mediterranean area, arundo was introduced to California in the late 1800s and used for erosion control along drainage canals. It continues to be sold and planted as an ornamental. Arundo is a highly invasive bamboo-like perennial grass that can form large, fast-growing, monospecific stands that outcompete and displace native riparian vegetation while restricting water flow, increasing sedimentation, and forming large debris piles in streams and rivers. It is not considered to be of value to native wildlife. Arundo spreads by growing rhizomes (lateral roots) and disperses to new sites when stems and rhizomes break off in floodwater and take root in moist streambed soils. Grading and other construction activities can and have greatly increased areas occupied by arundo. For example, Camp Pendleton's past program for clearing native vegetation to conserve water resulted in distributing arundo throughout the cleared area. When the program was halted, the arundo population continued to expand (Reiger 1988).

The effects of arundo's ability to alter ecosystem processes may be profound. It is far more susceptible to fire than native riparian species. However, although it recovers from fires, most native vegetation does not, leading to increased postfire dominance by arundo. By increasing sedimentation after establishing in stream channels, arundo stabilizes islands, hinders braiding and shifting patterns in stream channel movement, and prevents native stream channel vegetation from establishing (Peterson pers. comm.). An example of this can be seen at Stony Creek in northern California. Because arundo has a vertical structure, it does not overhang water like native riparian vegetation. The result is less shade over water, providing less cover, increased water temperatures, and altered water chemistry, all conditions that can harm fish and other existing aquatic organisms and ultimately change the aquatic species composition

By 1993, arundo accounted for as much as 50-60% of a 1,116-acre riparian community in the Riverside west quadrangle covering a portion of the Santa Ana River in southern California (Douthit 1993). Because of this, it has been implicated in the reduction of rare native stream fish populations in the Santa Ana River (Bell 1993). Some arundo populations have been mapped in southern California (Douthit 1993), and a population has been mapped along Stony Creek in northern California; however, no comprehensive statewide mapping of arundo has been conducted. Therefore, an accurate assessment of the extent and rate of spread of the weed is unknown. It is widespread throughout the Sacramento and San Joaquin River channels and their tributaries, as well as throughout the Delta. More survey mapping is needed to determine the extent of arundo, the levels of threat posed by the weed throughout the ERPP study area, how and when best to safely control it, and a prioritized strategy for removing it.

Tamarisk (*Tamarix chinensis, T. ramossisima, T. pentandra*), also known as salt cedar: This woody shrub from Eurasia was introduced in the early 1800s as an ornamental. It has since spread or been introduced into nearly every drainage system in the southwestern United States. It occupies 1.5 million acres nationwide and 16,000 acres in California. It can alter ecosystem processes such as the frequency of fires and hydrologic conditions of streams and groundwater. Tamarisk plants evapotranspire larger quantities of groundwater than do native plants, leading to reduced groundwater supplies. It traps more sediment than native vegetation, leading to a reshaping of stream bottoms and altered flooding pattern. It adds increased fuel loads to the riparian community, which can result in more fires. Tamarisk tolerates fires; native riparian species generally do not. The result of these ecosystem process changes is the eventual exclusion or reduction in cover by native plant species and altered stream shapes and flooding patterns. Studies have shown that bird usage is lower when tamarisk, rather than native tree species, dominates the riparian zone (Meents et al. 1984, Anderson and Ohmart 1984).

Tamarisk is widespread in California rivers; however, an accurate assessment of the extent and rate of spread of the weed is unknown. Like arundo, more survey mapping is needed to determine the extent of tamarisk, the levels of threat posed by the weed, the best time to safely control it, and a prioritized strategy for removing it.

Ailanthus, edible fig, northern California black walnut, eucalyptus, and black locust are examples of invasive trees or shrubs that have achieved local dominance in riparian forests in the ERPP study area. All have the potential for population expansions.

Ailanthus (*Ailanthus altissima*), also known as tree-of-heaven: Ailanthus was first introduced into the eastern United States in the late 1700s. By the mid-1800s, it was commonly sold by nurseries as a street and shade tree. It was introduced into California in the 1850s. Its horticultural popularity declined by the mid-1900s, and it became naturalized in mostly ruderal areas, but is often present in riparian habitats as well, especially those in agricultural or urban settings (Hunter 1995). Although it may not be as aggressive an invader as other riparian weeds, it has achieved local dominance in some sites, either displacing or preventing native riparian species from establishing. In agricultural settings, ailanthus roots can disrupt the integrity of levees and irrigation canal banks.

Edible fig (*Ficus carica*): Fig is a cultivated tree native to the Mediterranean area. Its seeds are dispersed by birds and other wildlife and by floodwaters. Present in many streams and rivers throughout California, it tends to form a shady canopy that can hinder seedling establishment by native species. It also spreads vegetatively through stump sprouting and where bent branches take root, thus forming thickets that exclude native species. An example of the fig's impacts may be seen at both the Dye Creek and Cosumnes River Preserves in northern California, where active management programs are in place to eradicate the trees.

Northern California black walnut (*Juglans californica var. hindsii*): Historically, the native northern California black walnut was present only along the Sacramento River between Freeport and Rio Vista (Fuller 1978). However, Skinner and Pavlik (1994) say it historically grew in Contra Costa, Napa, Sacramento, Solano, and Yolo Counties. It is a special-status species in its native range; however, it (or a hybrid of it and the English walnut, *Juglans regia*) is now common in many Central Valley, Delta, and Bay Area riparian forests. The walnut's widespread distribution may be explained by its historical use as rootstock in English walnut orchards and possibly by active spread by Native Americans. Along the mainstem of the Sacramento River, there are dense areas of northern California black walnut saplings established under the canopy of mature valley oaks and cottonwoods. Without active management, these trees could eventually displace valley oaks and cottonwoods in many areas.

Eucalyptus (*Eucalyptus* spp.): Eucalyptus trees are native to Australia. They have been used commercially as fuel wood and planted horticulturally in urban settings. They are fast-growing and quickly form canopies that restrict available light from slower-growing native species. They also compete for water and form a large leaf litter layer that alters the soil chemistry and tends not to break down rapidly. The oil in the trees makes them particularly hazardous to fires, as was demonstrated in the Oakland hills and southern California fires in the summer of 1996. However, unlike native riparian plants, eucalyptus resprouts after fires. This combination of characteristics leads to dominance and expansion of the trees in riparian systems. Because the leaves are not broken down, the leaf litter can cause increased sedimentation in streams, adversely affecting invertebrate and fish populations. Eucalyptus trees growing in stream channels at maturity create flood risks because their shallow roots and large stature render them vulnerable to blow down and toppling during storm events, potentially causing debris dams during high flows. Volunteer eucalyptus stands in the channel may be found in many riparian locations, such as along Putah Creek in Yolo County.

Black locust (*Robinia pseudoacacia*): Black locust is native to the eastern United States and is planted horticulturally in California. Once established, it spreads through seed and rhizomes to form locally dominant patches that can exclude native vegetation. Like eucalyptus, black locust resprouts after fires. Examples of its dominance may be found in sites along the Delta and lower American River and at the Cosumnes River Preserve.

Russian olive, perennial pepperweed, German ivy, cordgrass, and purple loosestrife are weeds that pose problems in a more restricted range or ecological zone type compared to the other listed weeds.

Russian olive (*Elaeagnus angustifolius*): Russian olive is a cultivated shrub or tree, native to temperate Asia. It is not yet a significant problem but can become one if not controlled. It is planted in landscaping and has been planted extensively in wind breaks. It spreads into riparian areas from seed and at maturity, crowds out native species.

Perennial pepperweed (*Lepidium latifolium*): Perennial pepperweed is a mustard family plant, native to Eurasia, that is widespread in the United States. It was introduced to North America in the early 1800s and reportedly first introduced to Yolo County as a contaminant of sugar beet seed (Young et al. 1996). It is found in all counties in the ERPP study area. It infests freshwater riparian and wetland areas and salt-affected areas, including coastal salt marshes, often where there was past disturbance. It can also grow in areas that are only seasonally wet. The plants grow fast, up to two or more meters tall, and spread both by rhizomes and seeds, forming dense stands that exclude all other vegetation. Once stems begin growing, most herbivores will not eat the plants (Young et al. 1996). An example of a perennial pepperweed infestation may be found at Grizzly Island in the Delta.

German ivy (*Senecio milkanioides*): This vine, native to South Africa, has been planted horticulturally and has spread into primarily coastal riparian forests. German ivy can be found in Marin and Sonoma County riparian forests. It carpets large expanses of forest understory and climbs to the canopy of willow and cottonwood trees. Competing for nutrients and water and preventing sunlight from reaching seedlings, it reduces the cover of native vegetation and the riparian community structure.

Cordgrass (*Spartina alterniflora, S. anglica, S. densiflora, S. patens*): *Spartina alterniflora*, native to eastern North America; *S. anglica, S. densiflora,* native to South America; and *S.*

patens, native to the southeastern United States were intentionally introduced to San Francisco Bay areas in the 1970s (Callaway and Josselyn 1992, Daehler and Strong 1994, Spicher and Josselyn 1985, Spicher 1984). All introduced cordgrasses are a threat to the open intertidal mud and salt marsh communities in estuarine areas. The cordgrasses form tall, dense colonies in the mud with thick root systems. The result is alteration of tidal flows and increased sedimentation, as well as displacement of clams, worms, crustaceans, and shorebirds that depend on these prey species. An additional threat is to the native *S. foliosa*, which becomes overgrown by *S. alterniflora* (Callaway and Josselyn 1992) and can hybridize with it (Strong and Daehler 1996). The native *S. foliosa* community provides habitats for the clapper rail and salt marsh harvest mouse.

Purple loosestrife (*Lythrum salicaria*): Native to Eurasia, this riparian herbaceous weed was introduced to North America in the early 1800s and has since invaded wetlands throughout the United States. It forms large monotypic stands, displacing native species, and can eliminate shallow open-water areas otherwise used by waterfowl and wildlife.

VISION

The vision for invasive riparian and salt marsh plant species is to reduce their adverse effects on native species and ecological processes, water quality and water conveyance systems, and major rivers and their tributaries.

Active management is necessary to reduce invasive plant populations that compete with the establishment and succession of native riparian vegetation in the Delta and Sacramento and San Joaquin Rivers and their tributaries in order to:

- assist in the natural reestablishment of native riparian vegetation in floodplains,
- increase shaded riverine cover for fish,
- reduce stress on rare species and communities, and
- increase habitat values for riparian associated wildlife.

Reduction of populations of invasive plant species that compete with the establishment and succession of native saline and fresh emergent marsh vegetation would also assist in the natural reestablishment of these native habitats and increase habitat values for associated wildlife. Developing and enhancing programs that protect and restore our State's natural resources and biological diversity while fulfilling our flood control, water conveyance, and compatible economic development needs are necessary if efforts are to succeed on a long-term basis. Historically, governmental weed control programs have been aimed at non-native species, which has adversely affected commerce, primarily agriculture, or public services such as water delivery. Weeds in natural areas have historically not been addressed but are now areas of great and increasing concern. Expanding existing governmental and private programs or creating new, similar programs is needed to perpetually monitor, research, and control weeds that impact natural areas, and to prevent new infestations by existing weeds or new introductions. To minimize recurring infestations, programs to actively restore native habitats will require expansion into areas where infestations have been removed.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

The California Department of Food and Agriculture's Integrated Pest Control Branch has responsibility for tracking and controlling federally listed noxious weeds statewide. These are weeds that have an impact on agriculture, although most of the current infestations are restricted to natural and uncultivated areas (O'Connell pers. comm.). Listed weeds are given an "A", "B", or "C" designation. "A" weeds are tracked and targeted for control or eradication wherever they are found. "B" weeds are considered too widespread to require mandated control measures; the choice for controlling them is left to the county agricultural commissioners. "C"-rated weeds are so widespread that the agency does not endorse State- or county-funded eradication or control efforts except in nurseries and seed lots. Of the weeds described in this vision statement, only perennial pepperweed and purple loosestrife are listed as noxious agricultural weeds, both with a "B" designation. With funding, the California Department of Food and Agriculture's Integrated Pest Control Branch could be expanded to include weeds adversely affecting natural areas and their existing infrastructure and expertise used to track, map, and control weeds that are problems in natural areas.

Two recently announced programs or policy changes may bear positively on the vision for controlling aquatic, riparian, and salt marsh weeds. The first is that the U.S. Department of Animal and Plant Health Inspection Service (APHIS) developed a new weed policy that includes regulation of all types of weeds, including not only those threatening agricultural or managed areas, but natural area weeds as well. The program will use a risk assessment to list and delist noxious weeds. Among other aspects of the new policy, APHIS will institute a regulatory role of detecting, assessing, and containing incipient infestations. The policy states that APHIS will play a federal coordination role to facilitate communication and cooperation between relevant public agencies and others.

The second new approach was formed through a Memorandum of Understanding (MOU) signed by 17 land-holding federal agencies in 1994. A committee was formed called the Federal Interagency Committee for Management of Noxious and Exotic Weeds. The purpose of the MOU and committee formation is to enable the signing agencies to cooperatively manage noxious and non-native weeds on federal lands and to provide technical assistance on private land to achieve the goal of sustainable, healthy ecosystems that meet the needs of society.

There are many other organizations with an interest in weed issues in the ERPP study area. All have different roles, interests, and expertise. To attain ERPP's goals, a coordinated effort would be needed among the groups to develop, prioritize, and implement weed management programs and strategies that will help to achieve ecological zone and resource visions.

- The University of California Weed Science Program in the Vegetable Crops Department conducts ongoing research on weed ecology and control, including noncrop and natural area problems.
- The California Exotic Pest Plant Council is a nonprofit organization that focuses on issues regarding non-native pest plants and their control, and on public education regarding the issues.
- The California Weed Science Society is a 50-year-old organization serving the weed science community.
- The U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and the California Department of Fish and Game have regulatory roles pertaining to weed control.

Several public and private groups dealing with weeds directly or indirectly in the ERPP study area can also be included. Among these are:

- the California Native Plant Society,
- The Nature Conservancy,
- State and national parks, county and local parks,
- U.S. Bureau of Land Management,
- APHIS,

- U.S. Army Corps of Engineers,
- U.S. Natural Resource Conservation Service,
- Center for Natural Lands Management,
- resource conservation districts,
- mosquito abatement districts,
- flood control districts,
- California Association of Nurserymen,
- Team Arundo, and Team Arundo del Norte,
- local land trusts,
- and private landowners.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Invasive riparian and salt marsh plants adversely influence other ecosystem elements such as riparian and riverine aquatic habitat, and fish, wildlife, and plant species.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for invasive riparian and salt marsh plants is to reduce populations of invasive non-native tree and shrub species that compete with native riparian vegetation. Reducing invasive riparian and salt marsh plants would help to establish and support sustainable native vegetation communities.

The general target for invasive riparian and saltmarsh plants is to prevent them from becoming established in riparian and saltmarsh restoration areas, conduct distribution and abundance surveys throughout the ERPP Study Area, and develop and implement control and eradication programs for high priority problem areas.

A comprehensive strategy to reduce invasive riparian and salt marsh plant populations and their adverse effects on the Bay-Delta ecosystem would include the following items.

- Assess weeds for their levels of a threat, their extent, and their potential for long-term control.
- Assess potential weed control sites for their likelihood to provide the greatest return on control efforts in terms of improved habitat quality and other benefits, such as reducing flood risk and channel instability, longevity of results, and ability to supply the types of habitats and habitat characteristics proposed for restoration.
- Develop and implement management plans based on the assessment of weeds and sites to achieve specific targets for each weed and site.
- Wherever necessary and appropriate, implement habitat restoration simultaneous with or following control measures.
- For arundo and tamarisk, eradicate the weeds in watersheds where they have only small populations, then concentrate on eradicating satellite populations extending beyond major infestations, and finally, reduce and eventually eliminate the most extensive populations.
- Provide technical expertise, serve as a clearinghouse for regional information and project results, and assist with implementing high-priority local projects in specific ecological units or zones to increase the effectiveness of existing public and private

programs to reduce the threat of invasive species.

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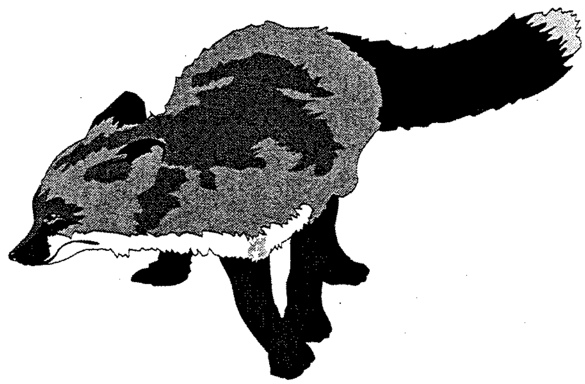


INTRODUCTION

The large-scale restoration of emergent wetlands, riparian habitat, and adjacent perennial grasslands will be the main focus of a strategy to reduce the adverse impacts of non-native wildlife on the health of the Bay-Delta ecosystem. The goal is a restored Bay-Delta and watershed where the quality, quantity, and structure of the restored habitat discourage colonization by non-native wildlife, provide a competitive advantage to native wildlife, and reduce the vulnerability of native species to nest parasitism and predation from species such as the brown-headed cowbird and starling, and from predation by species such as the red fox and Norway rat.

STRESSOR DESCRIPTION

One of the most serious environmental problems facing California is the explosive invasion of non-native pest plants and animals. Non-native plants, wildlife, fish, and aquatic invertebrates can greatly alter the ecosystem processes, functions, habitats, species diversity, and abundance of native plants, fish, and wildlife.

Many of these invasive species spread rapidly and form dense populations primarily by out-competing native species as a result of large-scale habitat changes that tend to favor non-native species and a lack of natural controls (e.g., natural predators). These non-native species usually have a competitive advantage because of their location in hospitable environments where the normal controls of disease and natural enemies are missing. As populations of non-native species grow, they can disrupt the ecosystem and population dynamics of native species. In some cases, habitat changes have eliminated connectivity of habitats that harbor the native predators that could help to limit populations of harmful non-native species.

The following common but harmful non-native species are found in the Bay-Delta area:

- The red fox was brought to California to be hunted for sport and raised for fur during the late 1800s and early 1900s. The population of this fox appears to be increasing and is now widespread in the Central Valley lowlands and the coastal counties south of Sonoma County. The range of this species also appears to be increasing, and the fox is a threat to many native endangered wildlife species such as the California clapper rail.

- The Norway rat was introduced unintentionally and was established in many areas by the mid-1800s. Increases in urban development, landfills, and riprap areas have resulted in large populations of these rats living along the bay shores. They are a threat to ground-nesting wildlife.

- The feral cat is a major predator to bird and mammal populations in the wetland areas of the Bay-Delta Estuary and wildlife areas elsewhere.

- The bullfrog is not native west of the Rockies but has been successfully introduced throughout most of California from Oregon to Mexico. Bullfrogs can establish and thrive in most permanent aquatic habitats that support emergent vegetation. Population levels in semipermanent aquatic habitats vary from year to year. Bullfrogs feed on most vertebrates and invertebrates that can be seized and swallowed.

- The red-eared slider is a turtle native to the southeastern United States and sold in pet stores throughout the west. The species has become established in the wild in some locations through releases by pet owners. The range and status of sliders in the Delta are unknown but it is possible that this species is successfully reproducing. If so, it could compete with aquatic species in and dependent on the Delta.

Non-native wildlife species have been sighted throughout the Sacramento and San Joaquin Valleys in a variety of habitats. These include aquatic, riparian scrub, woodland, and forest habitats; valley oak woodland; grassland and agricultural land.

Reestablishing connectivity between habitats would help to reduce non-native species. For instance, restoring the connection between Bay marshlands and upland habitats that have populations of coyotes may help to reduce populations of red fox. Nest conditions in fragmented areas of riparian habitats encourage nest predation and parasitism by non-native species such as starlings and brown-headed cowbirds. Restoring large blocks or broad bands of riparian habitats will eliminate or minimize these adverse effects. Larger blocks may also encourage additional nesting by native deep-forest-nesting species that have been previously excluded.

VISION

A non-native species is one that has been introduced into an area where it is not naturally found. The vision for non-native wildlife species is to implement a program to reduce the numbers of harmful non-native wildlife species (i.e., those that threaten the diversity or abundance of native species or the ecological stability of an area).

Reducing the numbers of non-native species and therefore the effects these species have on native wildlife will require a coordinated approach that includes restoring ecosystem processes and functions where applicable and possible, restoring native habitats, reducing or eliminating other stressors that suppress native species, and efforts to control non-native species.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Efforts to control non-native species, such as the red fox, are being undertaken on a small scale in the San Francisco Bay area. Most other efforts are associated with damage control in agricultural, urban, and suburban areas in the ERPP study area. Limited efforts have been focused in State and federal wildlife areas that have undertaken control programs on a small scale.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Non-native wildlife either compete with native wildlife species or prey on them. The result is diminished abundance of native species, some of which, such as the California clapper rail, are State or federally listed endangered species. Other than direct control measures, the problems caused by non-native wildlife species can be moderated by habitat restoration programs that reconnect habitats, reduce fragmentation of riparian habitat, and restore connection between lowland and upland habitats.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for non-native wildlife is to reduce the abundance of non-native wildlife species to maintain and expand the diversity or abundance of native species or the ecological stability of native habitats.

The general target for non-native wildlife is develop and implement control programs to reduce population abundance and to reestablish larger blocks of connected habitats to provide more extensive habitat and protection for native wildlife.

The Ecosystem Restoration Program Plan (ERPP) supports the following activities that would reduce adverse effects of non-native wildlife on native species:

- Reduce red fox populations in and adjacent to habitat areas suitable for California clapper rail, California black rail, salt marsh harvest mouse, and San Joaquin kit fox to reduce predation on eggs, juveniles, and adults and assist in the recovery of these native species.

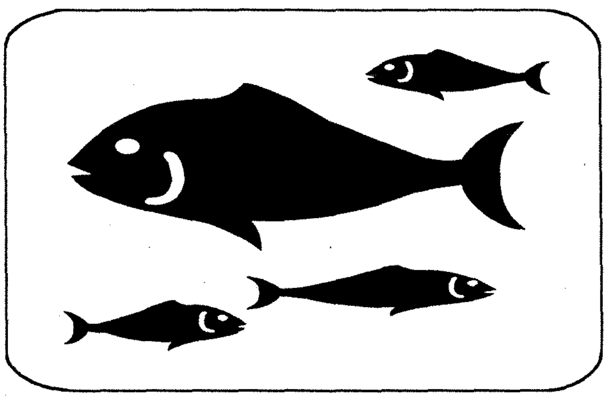
- Reduce Norway rat populations in and adjacent to suitable habitat areas for California clapper rail, California black rail, and salt marsh harvest mouse to reduce predation on eggs, juveniles, and adults and assist in the recovery of these species. A combination of activities would be required to prevent the rats from establishing in important habitat areas (e.g., remove garbage and rubbish; ensure proper construction of residences and food storage structures; break down stubble in field crops, such as corn, to expose the rodents to predation during winter) and reduce populations in important habitat areas where the rats are already established (e.g., use biological controls, practice the environmental controls listed above, and use rodenticides).

- Reduce feral cat populations in and adjacent to suitable habitat for California clapper rail, California black rail, salt marsh harvest mouse, San Joaquin pocket mouse, kangaroo rat, and blunt-nosed leopard lizard habitats to reduce predation on eggs, juveniles, and adults and assist in the recovery of these species.

- Periodically drain aquatic habitats inhabited by bullfrogs to reduce the populations of these species (bullfrog larvae have an extended growing season, sometimes even overwintering, compared to native amphibians such as the California red-legged frog).

- Investigate the feasibility of increasing the harvest of bullfrogs without disturbing native species.

- Implement a "buy-back" or "take-back" program in pet stores to reduce the number of red-eared sliders released into the Delta.



INTRODUCTION

Predation and competition are natural ecological functions; however, unnatural levels of each can result in adverse effects to important sport and commercial fisheries and species of concern such as winter-run chinook salmon. For example, the potential adverse effects of competition between native and hatchery-reared salmonid stocks for food and other resources are a concern. Predation on important fish species and stocks is known to be a problem in the Central Valley, however, at specific sites or under specific environmental conditions.

Efforts to control the extent of unwanted predation and competition, particularly the loss of species of concern, are an important component in restoring health to the Bay-Delta system and in providing for other beneficial uses of water.

STRESSOR DESCRIPTION

CHINOOK SALMON AS A PREY SPECIES

Predation occurs throughout the river and ocean life-history stages of chinook salmon, but the magnitude and extent of predation have not been quantified. There are essentially three classes of predators on chinook salmon: birds, fishes, and marine mammals. Predatory birds include diving birds such as cormorants and gulls; terns and mergansers; wading birds such as snowy egret, great blue heron, black-crowned night heron, and green heron; and raptors such as osprey.

Predatory fish include both native and non-native species. Native predatory species include Sacramento squawfish, prickly sculpin, and steelhead. Non-native predatory species include striped bass, white catfish, channel catfish, American shad, black crappie, largemouth black bass, and bluegill.

Predation by native species is a natural phenomenon and should not have a serious effect on naturally produced chinook salmon in areas where shaded riverine aquatic (SRA) habitat and other types of escape cover are present. Chinook salmon has coevolved with its native predators and has developed life-history strategies to avoid predation. However, predation by non-native species and increased predation resulting from artificial inwater structures and loss of instream habitat diversity may have resulted in gross imbalances in the predator-prey relationships and community structure in which chinook salmon evolved.

Artificial structures, such as dams, bridges, and diversions, create shadows and turbulence that tend to attract predator species and create an unnatural advantage for predators (Stevens 1961, Vogel et al. 1988, Decoto 1978). Specific locations where predation is of concern include Red Bluff Diversion Dam (RBDD), Glenn-Colusa Irrigation District's (GCID's) Hamilton City Pumping Plant, flood bypasses, release sites for salmon salvaged at the State and federal fish facilities, areas where rock revetment has replaced natural river bank vegetation, the Suisun Marsh Salinity Control Gates, and Clifton Court Forebay (CCF).

Predation at RBDD on juvenile chinook salmon is believed to be higher than natural levels because of the water quality and flow dynamics associated with the operation of this structure. The most important predator at RBDD is squawfish (Garcia 1989). Squawfish migrate annually upstream to RBDD from March to June, but some squawfish are present year round at the dam. Striped bass have also been captured immediately below RBDD in limited but regular numbers and have been found to have fed on juvenile salmonids (U.S. Fish and Wildlife Service unpublished data cited in Garcia 1989, Villa 1979). Striped bass were also observed by U.S. Fish and Wildlife Service (USFWS) divers below RBDD in September 1982, and five American shad captured at RBDD in June 1976 contained two to seven juvenile salmon each (Hall 1977).

Some chinook, such as juvenile winter-run chinook salmon that migrate downstream soon after emerging from the gravel in summer and early fall, will encounter RBDD when the gates are still down. They must cross Lake Red Bluff when turbidity is generally low and water temperatures are still relatively high. Because of their small size, these early emigrating winter-run juveniles may be very susceptible to predation in the lake by squawfish and cormorants (Vogel et al. 1988). In passing the dam, juveniles are subject to conditions that greatly disorient them, causing them to be highly susceptible to predation by fish or birds.

Late-migrating juvenile chinook salmon that pass RBDD in early spring most likely suffer the greatest losses because squawfish abundance is higher at this time of year and river conditions are generally favorable for predators, especially during dry years. The impacts of these losses are also more important because of the overall higher survival of these smolts (versus actively migrating fry) and their greater probability of contribution to the adult population.

There are some concerns that predation is higher in flood bypasses. In one survey of the Sutter Bypass, the most abundant species captured included chinook salmon and Sacramento squawfish (Jones & Stokes Associates 1993a).

GLENN-COLUSA IRRIGATION DISTRICT HAMILTON CITY PUMPING PLANT

Evaluations at GCID Hamilton City Pumping Plant suggested that predation could be an important factor contributing to losses of juvenile salmonids at that location (Decoto 1978). In mark-recapture studies, 66% of the salmon were unaccounted for in bypass evaluations, and 82% were unaccounted for in culvert evaluations. More recent studies suggest that Sacramento squawfish is the primary predator at the pumping plant (Cramer 1992), although striped bass were also found with young chinook salmon in their stomachs.

FISH SALVAGE RELEASE SITES

Orsi (1967) evaluated predation at the Jersey Island release site for salvaged fish from the State and federal fish facilities from mid-June through July in 1966 and 1967. Striped bass was the major predator at the release site, with black crappie and white catfish ranking second and third, respectively. Orsi estimated that overall predation occurred on about 10% of the salvaged fish released per day during multiple releases (one million fish/day), and more than 80% of the predation was from striped bass. He qualified this estimate as potentially being high and not applicable to other sites such as the Sacramento River. Similarly, Pickard et al. (1982) conducted predation studies of salvage release sites from 1976 to 1978. Fish, salvaged from the State's fish facility, were regularly transported and released into the lower Sacramento River at Horseshoe Bend. More predator fish were collected at the release site than at the control site, with striped bass and Sacramento squawfish being the primary predators. Also, more fish remains were found in the predators' stomachs at the release site than at the control site.

ROCK REVETMENT SITES

USFWS conducted a study to assess the relationship of juvenile chinook salmon to the rock revetment type bank protection between Chico Landing and Red Bluff (Michny and Hampton 1984). They found that predatory fish, such as Sacramento squawfish and prickly sculpin, were more abundant at riprapped sites than at naturally eroding bank sites with riparian vegetation. Conversely, juvenile salmon were found more frequently in areas adjacent to riparian habitats than at riprapped sites. Riparian habitats provide overhead and submerged cover, an important refuge for juvenile chinook from predators.

CLIFTON COURT FOREBAY

Overall predation rates for salmon smolts in CCF have been estimated at 63-98% for fall-run chinook (California Department of Fish and Game 1993a), and 77-99% for late-fall-run chinook (Table 4). In mark-recapture studies, estimated mortality rate per mile in CCF was 91.3%, compared with 2.7% for the central Delta and 0.9% for the mainstem Sacramento River (between Ryde and Chipps Island). This difference was thought to result from the greater abundance of predators, primarily striped bass, in CCF, as well as hydraulic actions and the operational and physical design of CCF. During high tide, striped bass density in CCF has been estimated to be three to 17.5 times higher than the density of striped bass in the Delta. At low tide, striped bass density in CCF has been estimated as roughly five to 21 times higher than in the Delta.

SUISUN MARSH SALINITY CONTROL STRUCTURE

The California Department of Fish and Game (DFG) conducted predation studies from 1987 to 1993 at the Suisun Marsh salinity control structure to determine if the structure attracts and concentrates predators. The dominant predator species at the structure was striped bass, and juvenile chinook were identified in their stomach contents. Catch-per-unit-effort (CPUE) of bass has generally increased at the structure from 1987 (less than 0.5, preproject) to 1992 (3.0, postproject), and declined somewhat in 1993 (1.5) (California Department of Fish and Game 1994c). In comparison, CPUE was 3.44 at CCF and 1.65 at the south Delta barriers during the same period, using identical gear.

OCEAN PREDATION

Ocean predation very likely contributes to natural mortality in naturally and hatchery-produced chinook salmon stocks; however, the level of predation is unknown. In general, chinook salmon are prey for pelagic fishes, birds, and marine mammals including harbor seals, sea lions, and killer whales. There have been recent concerns that rebounding seal and sea lion populations, following their protection under the Marine Mammal Protection Act of 1972, have resulted in substantial mortality for salmonids.

Ocean predation rates on Central Valley chinook salmon have not been evaluated, but several studies have been conducted in other estuaries. At the mouth of the Russian River, Hanson (1993) found that maximum population counts of seals and sea lions corresponded with peak periods of salmonid returns to the hatchery upriver. However, Hanson concluded that predation was minimal on adult salmonids because only a few pinnipeds foraged in the area, their foraging behavior was confined to a short portion of the salmonid migration, and their capture rates were low.

In the lower Klamath River, Hart (1987) reported predation rates of about 4% and 8% in 1981 and 1982, respectively, from harbor seals on chinook, coho and steelhead. It is important to note that marine mammal and chinook salmon populations evolved together and coexisted long before humans played a role in controlling either species.

Summary of Clifton Court Forebay Prescreen Loss Studies on Hatchery Juvenile Chinook Salmon

Date	Salmon Run	Prescreen Loss Rate (%)	Temperature (avg/day°F)	Pump Exports (avg. af/day)	Predator Abundance	Size at Entrainment (mm fl)
Oct 76	Fall	97.0	65.4	2,180	NA	114
Oct 78	Late-fall	87.7	57.5	4,351	NA	87
Apr 84	Fall	63.3	61.2	7,433	35,390	79
Apr 85	Fall	74.6	64.1	6,367	NA	44
Jun 92	Fall	98.7	71.7	4,760	162,281	77
Dec 92	Late-fall	77.2	45.4	8,146	156,667	121
Apr 93	Fall	94.0	62.0	6,368	223,808	66
Nov 93	Late-fall	99.2	53.7	7,917	NA	117

NA = estimates not available

Source: California Department of Fish and Game 1993.

General Analysis of Striped Bass Predation on Chinook Salmon

Food habit studies conducted by numerous investigators indicate that chinook salmon are not an important component in the diet of striped bass, although, at times, young salmon, primarily fall-

run, have constituted a substantial part. Generally, this has occurred in the Sacramento River upstream of the estuary and has been localized at water management structures, bridge abutments, and other predator habitats. It also occurs at structures that cause disorientation of juveniles such as RBDD. In the Delta, it is a known problem in CCF and at sites where large numbers of artificially produced chinook salmon are released.

The studies reveal that, except at localized sites and structures, striped bass are less likely to eat salmon in Suisun Bay and the Delta than in the rivers above the Delta. The greater vulnerability of salmon in the river may be a result of the greater clarity and the smaller width of the river. In many areas, bank protection activities, such as maintaining levees and riprapping, have removed SRA habitat and eliminated escape cover needed by young fish.

Opportunities to Reduce Predation

There have been only limited efforts to reduce predation problems. At RBDD, a squawfish derby was held in 1995 to reduce squawfish abundance. However, this sport fishery is unlikely to measurably alleviate predation from a native migratory species. The fishery could temporarily reduce squawfish abundance, but more squawfish are likely to repopulate the area. Sacramento squawfish are also more abundant at RBDD during spring, and a spring fishery could cause incidental catches of winter-run chinook.

The preferred solution to reduce predation at RBDD is to eliminate or reduce the feeding habitat that RBDD creates by seasonally or permanently raising the gates. It is anticipated that the GCID Hamilton City Pumping Plant will be redesigned and relocated on the main channel of the Sacramento River, upstream of its present location on an oxbow. The new design will eliminate predator habitats and should substantially reduce the existing level of predation and other problems caused by stream channel and gradient changes in the Sacramento River in recent years.

Predation problems occurring in CCF may be resolved by alternative conveyance facilities that reduce the quantity of water drawn directly into the forebay from the Delta.

Another important opportunity to reduce predation on target fish species is by recreating or restoring a more complex mosaic of instream habitats. These habitats can contribute to reduced predation and competition by allowing species to partition themselves among a more diverse array of available habitats.

PREDATION AND COMPETITION WITH HATCHERY-REARED FISH

The extent of predation by hatchery salmonids on naturally produced chinook salmon and steelhead is also not known. Steelhead releases, primarily by the Coleman National Fish Hatchery, may have the greatest potential for inducing unnatural levels of predation on naturally produced chinook salmon. Coleman National Fish Hatchery has a capacity to raise about one million yearling steelhead. Present production targets a release of about 600,000 in January and February at 125-275 millimeters (mm) long (four fish/pound). Predation on hatchery-produced steelhead is thought to be further reduced because these steelhead tend to outmigrate rapidly and during a period when inriver foraging conditions are suboptimal (i.e., high turbidity, low water temperature).

Predation by residualized hatchery-released steelhead, however, could be substantial. The extent of residualization of released steelhead trout smolts is unknown. With a potential annual release of more than one million steelhead trout at Coleman National Fish Hatchery, even a small rate of residualization could result in a substantial predator population.

Predation from steelhead released by Feather River Hatchery and Nimbus Fish Hatchery has not been evaluated but may also be important. Each of these hatcheries has a capacity to raise about 400,000 yearling steelhead to a size of 3-4 fish/pound. Feather River Hatchery fish are planted in the Feather River below Yuba City, most by the end of March, and the Nimbus Fish Hatchery fish are mainly trucked and released in the Carquinez Strait between January and April (California Department of Fish and Game 1990). Feather River hatchery steelhead are released at a large enough size and at a time when they could intercept winter-run chinook. Nimbus Hatchery steelhead would also be large enough to prey on winter-run chinook salmon.

Chinook salmon and steelhead artificially produced at and released from hatcheries may compete with (or displace) their naturally produced counterparts for food or habitat in the river, estuary, and open ocean. The major source of competition from hatchery salmonids in the upper Sacramento River would be from releases from the Coleman National Fish Hatchery on Battle Creek. The extent of competition between naturally produced chinook and releases from other hatcheries is of particular concern. The extent of this competition is unknown but is believed to be low. The size differences between the various chinook salmon stocks may also result in segregation according to size-dependent habitat preferences because juvenile chinook salmon and steelhead move to faster and deeper waters as they grow and do not compete with fry (Everest and Chapman 1972).

Competition between hatchery runs and naturally produced salmon in the ocean is most likely limited in most years. The ocean environment has been assumed to be nonlimiting because, historically, the abundance of wild salmon was much higher than the combined abundances of wild and hatchery salmon at present (Chapman 1986, Bledsoe et al. 1989), and standing stocks and production rates of prey resources were estimated to far exceed the food requirements of the present ocean populations (LaBrasseur 1972, Sanger 1972). A number of studies have found evidence that ocean conditions may limit salmon production and a substantial percentage of the total natural mortality may occur during early marine life (Parker 1968, Mathews and Buckley 1976, Bax 1983, Furnell and Brett 1986, Fisher and Pearcy 1988). However, in many populations, much of this mortality appears to occur in the first month at sea regardless of the number of smolts released. Brodeur et al. (1992) suggested that local depletion of resources could occur, especially of fish prey in a warm year of reduced productivity (e.g., in 1983) when prey were smaller and competitors, such as mackerel, were abundant. But, in general, juvenile salmon do not appear to be food-limited in coastal waters during most normal years (Brodeur et al. 1992, Peterson et al. 1982, Walters et al. 1978).

VISION

The vision for predation and competition is to reduce unnatural levels to restore fish populations by removing, redesigning, or reoperating inwater structures, diversion dams, and hatchery practices.

The ERPP vision for unnatural levels of predation and competition is closely linked to physical habitat restoration objectives and targets in the visions for the Sacramento River Ecological Zone, the Sacramento-San Joaquin Delta Ecological Zone, the San Joaquin River Ecological Zone, and the Suisun Marsh/North San Francisco Bay Ecological Zone. In addition, the visions for chinook salmon, steelhead trout, striped bass, and artificial production contain strategies to ameliorate the adverse effects of competition and predation. Cumulatively, these visions present a robust integration of implementation objectives, restoration targets and actions that will contribute substantially to the restoration and maintenance of a healthy ecosystem, and healthy populations of valuable sport and commercial fisheries.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Three major programs to restore chinook salmon and steelhead populations exist within the Central Valley. The Secretary of the Interior is required by the Central Valley Project Improvement Act (Public Law 102-575) to double the natural production of Central Valley anadromous fish stocks by 2002. The National Marine Fisheries Service is required under the Endangered Species Act to develop and implement a recovery plan for the endangered winter-run chinook salmon and to restore the stock to levels that will allow its removal from the list of endangered species. DFG is required under State legislation (The Salmon, Steelhead Trout and Anadromous Fisheries Program Act of 1988) to double the numbers of salmon and steelhead trout that were present in the Central Valley in 1988.

These programs, together with the ecosystem approach provided in ERPP, will cumulatively provide for substantial improvements in the health of fish populations, their habitats, and the ecosystem processes that create and maintain habitat and lessen the adverse effects of stressors.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

The solutions to reducing unnatural levels of predation and competition are linked to improved hatchery management strategies which include reevaluation of release programs for hatchery produced fish. The solution also include modification to structures that promote predation such as predator habitat provided by instream structures. Some structures, such as RBDD, increase the vulnerability of young fish to predation. The restoration of riparian and riverine aquatic habitats, set back levees, and increases in the area and quality of shallow water habitat throughout the Delta and Suisun Bay will also provide important ecological components to lessen species interactions and the potential for predation.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for predation and competition is to reduce the loss of juvenile anadromous and resident fish and other aquatic organisms from unnatural levels of predation in order to increase survival and contribute to the restoration of important species.

The general target is to develop and implement hatchery practices to reduce the potential interactions and competition between artificially produced and naturally produced chinook salmon, steelhead, striped bass, and other resident and estuarine fish. Predation and competition can be further reduced by restoring complex and diverse habitats throughout the mainstem rivers and Bay-Delta.

Actions which can contribute to this vision include:

- reducing shadows and turbulence created by dams, bridges, and diversions that attract predator species,
- replacing or supplementing rock revetment site with natural vegetation including shaded riverine aquatic habitats,
- restoring large blocks of riparian and shaded riverine aquatic habitats along the mainstem Sacramento and San Joaquin Rivers,
- preventing predatory fish from congregating below the Red Bluff Diversion Dam by modifying operations,
- improving fish passage through the flood control bypasses and eliminating low areas with no connection to perennial water courses,
- improving fish release sites used by the State and federal Delta fish salvage facilities,
- reevaluating opportunities to reduce predation in Clifton Court Forebay,
- evaluate alternate release strategies for Central Valley hatcheries to minimize interactions between hatchery and naturally produced fish,

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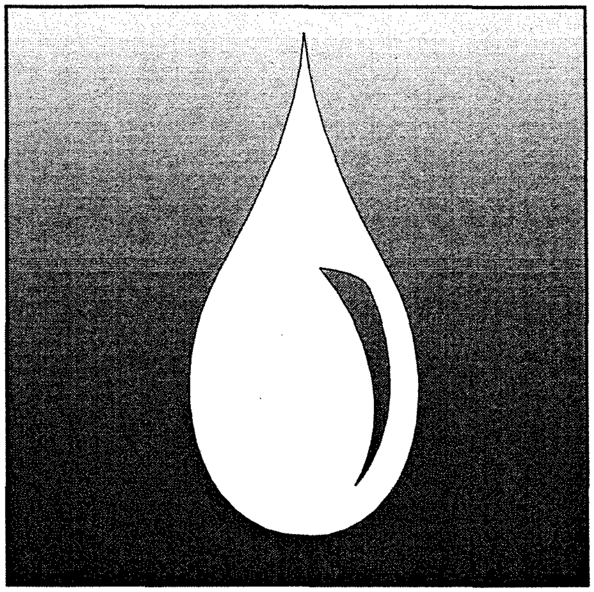

INTRODUCTION

Contaminants are inorganic and organic compounds and biological pathogens that introduce the risk of adverse physiological response in humans, plants, fish, and wildlife resources through waterborne or food-chain exposure. Contamination by these compounds may cause acute toxicity and mortality or long-term toxicity and associated detrimental physiological responses, such as reduced growth or reproductive impairment. Contaminant toxicity has been documented in shellfish, fish, mammal, and bird species from the Bay-Delta. The most serious contaminant problems in the Bay-Delta and its mainstem rivers and tributaries come from mine drainage, agricultural drainage, and urban runoff.

ERPP recognizes that water quality in the Delta must be protected and improved for all beneficial uses including municipal and domestic water supply, irrigation, stock watering, contact and noncontact water-related recreation, hydroelectric power generation, industrial service supply, warm and cold freshwater habitat, warmwater and coldwater spawning, fish migration, and wildlife habitats.

Although cause-and-effect relationships between levels of contaminants and the abundance of aquatic resources have not been conclusively documented, ERPP envisions a restored, healthy Bay-Delta ecosystem in which contaminant loads and concentrations are reduced to levels that do not interfere with primary and secondary productivity, nutrient cycling, and foodweb support. Such a restored ecosystem would no longer necessitate human health warnings about consuming fish and wildlife caught in the Bay-Delta estuary.

STRESSOR DESCRIPTION

An estimated 5,000-40,000 tons of contaminants enter the Bay-Delta annually. They are distributed according to complex flow patterns that are heavily influenced by inflow from rivers and the amount of water being pumped from the Delta. Although research confirms that toxicants are affecting lower trophic-level resources to varying degrees in the Bay-Delta, ecosystem- and population-level effects are not well understood. Researchers disagree about the role that contaminants have played in the current poor health of the Bay-Delta.

There are three types of contaminants, inorganic, organic, and biological, present in the Bay-Delta ecosystem. Inorganic contaminants are substances such as heavy metals, phosphates, and nitrates that enter the Bay-Delta ecosystem primarily in treated municipal wastewater, industrial effluent, agricultural and mine drainage, and urban runoff. Heavy metals in the water column usually occur in trace amounts. They do not break down organically; however, even small amounts of some metals can be toxic. In addition, some metals bioaccumulate within food chains in plant and animal tissue to levels that can be toxic to higher trophic organisms. The heavy metals of greatest concern in mainstem rivers and tributaries of the Bay-Delta are cadmium, copper, mercury, and zinc.

Organic contaminants such as polychlorinated biphenyls (PCBs), plastics, pesticides, fertilizers, solvents, pharmaceuticals, and detergents enter the ecosystem primarily through urban and agricultural runoff. Because they decompose very slowly, some organic contaminants (e.g., DDT and PCBs) remain in the environment for long periods and may accumulate in aquatic foodwebs to levels that are toxic.

Biological pathogens, such as viruses, bacteria, and protozoans that cause disease, enter the system through improperly treated municipal sewage, septic systems, farm and feedlot runoff, recreational boat discharges, and urban runoff. Of particular concern to humans are bacteria that cause cholera, hepatitis, salmonella, and typhoid.

Contaminants are present in varying degrees in the water column and sediments of aquatic habitats in all 14 ecological zones of the ERPP study area. Contaminants are suspected or known to adversely affect the sustainability of healthy aquatic foodwebs and interdependent fish and wildlife populations. They also may play a key role in altering the composition of biological resources within affected aquatic and wetland habitats.

In the Sacramento River Basin, acidic drainage water from abandoned mine tailings contribute significant amounts of cadmium, copper, zinc, and mercury to tributaries and mainstem rivers that eventually flow into the Delta. Acute toxicity caused by these trace metals has resulted in fish kills, and long-term exposure is detrimental to growth and impairs reproduction. Of immediate concern is the potential hazard associated with mine drainages just upstream of the spawning area for the endangered winter-run chinook salmon on the Sacramento River. Because of elevated mercury levels, the Bay-Delta, Clear Lake, and Lake Berryessa have consumer advisories for consumption of fish. There are various mercury sources in the Sacramento River watershed including abandoned mines and Coast Range geologic sources.

In the San Joaquin River Basin, selenium leaches into agricultural drainage water during intense irrigation of selenium-rich soils. Selenium has caused reproductive failure in sensitive fish species and developmental deformities in waterfowl and shorebirds. Selenium is also prevalent in the San Francisco Bay, resulting from oil refinery discharges. Loadings of selenium into the Bay-Delta have caused an increase in concentrations of these contaminants in benthic invertebrate, fish, and wildlife populations. Concentrations of some contaminants in water, sediments, and biota of the Bay-Delta estuary are elevated compared with levels at reference sites.

In the Sacramento and San Joaquin River basins, runoff from agricultural crops, pasturelands, and orchards has introduced contaminants into tributaries and mainstem rivers, which ultimately flow into the Delta estuary and Bay. Organophosphate insecticides, such as carbofuran, chlorpyrifos, and diazinon, are present throughout the Central Valley and are dispersed in agricultural and urban runoff. Dormant spray pesticides enter rivers in winter runoff and enter the estuary in concentrations that can be toxic to invertebrates. Although the use of these chemicals has been banned, organochlorine pesticides (e.g., chlordane, DDT, and toxaphene) and organochlorine compounds (e.g., PCBs) persist in the environment. Because they accumulate in living organisms, they can become potent toxicants to fish and wildlife as they move up through the foodweb. Chlorinated pesticides are still being detected in fish and wildlife within the Delta and throughout the world.

Effluents from municipal and industrial sources are common components of mainstem rivers entering the Delta Estuary and Bay. These effluent flows may need to be reduced to restore the health of native fish and wildlife by reducing long-term and acute effects that alter aquatic foodwebs and impair the reproductive potential of these species.

VISION

The vision regarding contaminants is to ensure that all waters of mainstem rivers and tributaries entering the Bay-Delta, and all waters of the Bay-Delta, are free of high concentrations of toxic substances. The Ecosystem Restoration Program Plan (ERPP) would prevent, control, or reduce damaging levels of high-priority contaminants by remediating mine wastes, minimizing boat discharges and dredging effects, managing flows, restoring habitat, managing watersheds, and supporting existing programs for controlling agricultural and urban point and nonpoint sources.

ERPP recognizes the complexities inherent in defining processes related to toxic substances and biological responses in the Bay-Delta estuary, where processes operate over a wide range of space and time scales and flow regimes. The process of ecosystem restoration would be initiated by implementing actions to prevent, control, and reduce contaminant sources that represent immediate or potential toxicological hazards to ecosystem processes. The following describes actions that would help to achieve the ERPP vision for contaminants.

One goal is to remediate abandoned mines that contribute significant amounts of heavy metals, sediments, acidified water, and other pollutants to tributaries and mainstem rivers, thereby increasing contaminant loading to the Bay-Delta estuary. Water degradation from mine drainage water can be reduced by controlling runoff based on water quality objectives for specific contaminants; regrading, sealing, and reclaiming strip-mined lands by restoring physical habitat; or using biological or chemical inhibitors to reduce acid formation.

If necessary, financial incentives could be provided to farmers who successfully implement practices to reduce contaminant loading in Central Valley waterways. The successful reduction of rice herbicides in the Sacramento River demonstrates that it is possible to successfully control nonpoint-source contaminants through cooperative efforts by farmers and regulators.

Land use conversion for habitat restoration has the potential to help reduce pesticide, herbicide, mineral salt, and trace element loadings. Converting land from agricultural uses to native wetland and upland habitats would reduce the concentrations and loads of contaminants associated with current agricultural uses. Modifying current farming practices in other areas to be more "wildlife friendly" by changing cultivation practices, introducing postharvest flooding, and reducing pesticide and herbicide application rates would also support reductions in contaminants that could affect adjacent aquatic resources.

ERPP also proposes to reduce the concentration of contaminants entering the Bay-Delta and its tributaries by improving drainwater management. Measures could include reusing drainwater, managing groundwater, scheduling releases to the San Joaquin River to coincide with flows sufficiently large to dilute concentration or acquiring dilution flows from willing sellers, installing drainwater evaporation systems, and encouraging on-farm bioremediation using flow-through systems. Land may be retired and irrigation stopped in areas where soils drain poorly; overlay shallow, selenium-laden groundwater tables; or are only marginally productive.

Reducing urban and industrial contaminant loading to the Bay-Delta estuary could be accomplished by assisting formation of partnerships between dischargers and regulators. Using this approach, incentives could be provided to encourage improved source control, better urban planning and development, and wastewater recycling projects that reduce contaminants.

Dredging activities should be monitored and practices developed and implemented to reduce the release and resuspension of toxic substances in contaminated sediments and the discharge of contaminated water from dewatering operations. Studies are needed to evaluate opportunities for reuse of dredged material for proposed ERPP and other habitat restoration projects.

Wetlands management should be considered as a possible means to improve water quality by controlling natural, wastewater, and stormwater contaminants. Wetlands can retain contaminants or reduce loadings by converting contaminants through biochemical processes to less-harmful forms; wetlands also stabilize sediments. Without properly managing contaminants, however, wetlands can degrade and subsequently threaten the food chains they support.

Risks of bacterial and viral contamination from domestic wastewater could be reduced by enforcing boat-discharge regulations in the Bay-Delta estuary and tributaries, reducing recreational overuse and building of recreational homes near streams or Delta waterways, and endorsing wastewater reclamation projects.

Point- and nonpoint-source contaminants can be reduced by developing or implementing existing watershed management plans that effectively reduce contaminant loadings affecting ecosystem processes. Management practices that reduce loading include reducing contaminant loading to reservoirs, protecting groundwater, controlling erosion, reclaiming mines, better planning for land use, controlling animal waste, and screening and identifying nonpoint-source contaminants.

Studies are needed to determine if sediments in the Bay-Delta are toxic. Successfully reducing contaminant loadings will require working closely with agencies that have regulatory authority to develop water and sediment quality objectives for contaminants of concern for which none have been set.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

The CALFED Water Quality Program goal is to provide good water quality for environmental, agricultural, drinking water, industrial, and recreational beneficial uses. The water quality program includes programmatic actions to reduce water quality degradation for agricultural drainage, urban and industrial runoff, acid mine drainage, wastewater and industrial discharges, and natural sources which affect Bay-Delta water quality.

The geographic scope of the CALFED Water Quality Program is the legally defined Delta. This program is developing a strategy to resolve water quality problems that affect beneficial uses of the estuary. Included in this strategy is the intent to resolve water quality problems for certain species (e.g., anadromous fish) that inhabit the Delta but may be impacted at different life stages by conditions outside the Delta. In resolving the water quality problems of the Delta, CALFED may undertake actions throughout the ERPP Study Area.

Other ongoing water quality and contaminant monitoring programs are administered by the California Department of Water Resources, State Water Resources Control Board and the regional water quality control boards, U.S. Environmental Protection Agency, U.S. Geological Survey, local water districts, and many other local agencies and organizations. Some of these programs have made significant progress in controlling contaminant loading to the Bay-Delta, primarily by controlling point-source discharges from municipal wastewater treatment plants and industrial facilities. Monitoring programs that identify long-term trends in contaminants found in ecosystem biota have helped to guide restoration efforts. Current programs in the Bay-Delta are beginning to focus on assessing the toxic effects on ecosystem processes, identifying transport and fate of toxic substances, and quantifying ecological responses to toxic substances.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

The presence of contaminants in the Bay-Delta system can adversely impair efforts to restore fish, wildlife, and plant species to a healthy state. The individual species affected vary throughout the system and the adverse effects or presence of contaminants varies as well. For example, juvenile winter-run chinook salmon rearing in the Sacramento River below Keswick Dam can be harmed by heavy metals originating from Iron Mountain Mine. Lower in the system, all aquatic organisms can be adversely effected after storms by runoff of acute levels of pesticides applied in the late winter and early spring to orchards. Riparian communities can be adversely effected by overspray of herbicides.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective is to reduce concentrations and loading of contaminants in the aquatic environment and the subsequent bioaccumulation by aquatic species. Reducing contaminants would increase survival of aquatic species and eliminate public health concerns resulting from accumulation of toxins in tissues.

The general target for contaminants is to reduce loading, concentrations, and bioaccumulation in the food chain to levels that do not impair other efforts to restore health to fish, wildlife, and plant populations in the ERPP Study Area.

Agricultural point- and nonpoint-source controls on pesticides, herbicides, mineral salts, and trace elements could be achieved using best management practices such as:

- improving irrigation and tillage techniques,
- placing areal restrictions on pesticide spray and using integrated pest management to reduce pesticide use and consequent discharge to waterways during rainstorms,
- improving fertilizer application technologies,
- altering the amount of time pesticides are present, and
- improving water-use efficiencies.

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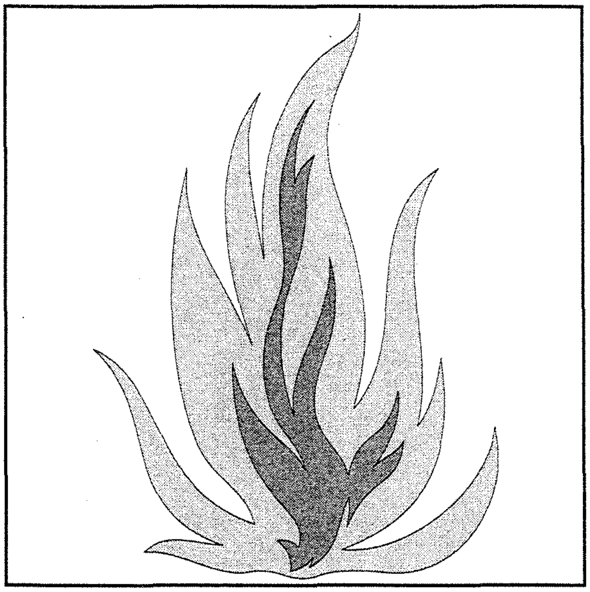


INTRODUCTION

Fire plays an important role in grassland and shrubland health by reducing fuel and promoting plant succession and reproduction. By suppressing fires, humans have had a large effect on the ecological role of natural fires; however, there are potential opportunities to expand the use of prescribed fires for restoring and maintaining grassland and shrublands.

Although fire is an important ecosystem process, reducing catastrophic wildfires and their consequences will help to achieve a healthier ecosystem that will better provide for the needs of plants, animals, and people using the system. This healthy ecosystem would include a range of sustainable habitat types that provide water supply, environmental, recreational, and aesthetic benefits that will be less vulnerable to the direct and indirect effects of catastrophic wildfires.

At lower elevations of the Bay-Delta watershed, protecting riparian habitat, grassland, and seasonal wetland habitats from catastrophic wildfires, while allowing carefully planned fires during appropriate times of year in seasonal wetlands and grasslands, is particularly important.

Fish and wildlife habitats should be protected from accidental fires originating from adjacent agricultural or recreation areas. At the same time, agricultural and residential areas should be protected from accidental fires originating in adjacent fish and wildlife habitat or recreation areas. Fire on Delta islands with high percentages of organic peat soils should be suppressed to the extent possible to avoid accelerated subsidence that could undermine the stability of levees, roads, and water conveyance structures.

STRESSOR DESCRIPTION

Wildfires, under conditions of unnaturally high fuel levels in tributary watersheds of the Bay-Delta, threaten fish and wildlife habitats through deforestation and resulting high levels of erosion and increased rates of surface runoff.

Wildfires can adversely affect habitats for a variety of fish and wildlife species and plant communities, including many special-status species and plant communities. Coastal scrub and chaparral provide habitats for a variety of wildlife. Many rodents inhabit chaparral; deer and other herbivores often make extensive use of this habitat type, which provides critical summer foraging areas, escape cover, and fawning habitat. Chaparral provides a variety of habitat needs for birds including seeds, fruits, and insects for food; protection from predators and climate; and singing, roosting, and nesting sites. In California, oak woodland and savanna are home to as many as 29 species of amphibians and reptiles, 79 species of birds, and 22 species of mammals. Many species are also dependent on annual and perennial grasslands. Some of the more arid-grassland species, such as the San Joaquin kit fox, are listed as threatened or endangered under the California and federal Endangered Species Acts (ESAs). Riparian habitats provide food; water; migration and dispersal corridors; and escape, nesting, and thermal cover more than 147 species of birds and 55 species of mammals.

Fire is an important primary ecosystem process that influences plant succession and germination and affects the amount and timing of runoff to watershed streams. Fire suppression activities have reduced the frequency and size of fires. This intervention has, in certain locations and at certain times, resulted in ever-increasing fuel-load levels. In these areas, wildfires can be extremely damaging, burning at significantly higher temperatures than those under more natural conditions that can adversely affect soil chemistry, remove all protective groundcover, and destroy the roots of crown-sprouting shrub species.

Land uses, such as residential and industrial development, land reclamation, livestock grazing, and agricultural practices, have contributed to changes in native plant communities and fragmentation of habitats that have made some areas more vulnerable to catastrophic wildfires.

VISION

The vision for wildfire is to support programs that will reduce the acreage and frequency of catastrophic wildfires and the consequences of wildfires. Reducing the extent and effects of wildfires in tributary watersheds of the Bay-Delta would reduce the threats posed by catastrophic wildfire on fish and wildlife habitats through deforestation and resulting high levels of erosion and increased rates of surface runoff.

The Ecosystem Restoration Program Plan (ERPP) proposed to manage and use fire as a tool to restore and maintain native habitats. Fire would be used to maintain a matrix of landscape conditions that should provide essential resources for all species, especially communities or assemblages of species that are rare within the ERPP study area. This should include restoring conditions needed for natural plant succession and germination throughout the landscape and for the full range of ecosystem processes characteristic to the area.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

The U.S. Forest Service, U.S. Bureau of Land Management, National Park Service, California Department of Forestry and Fire Protection (CDF), and local fire districts are charged with implementing effective fire management, fire suppression, and habitat restoration in their areas of responsibility. DFG and other resource agencies have coordinated with agencies such as CDF to develop annual fire suppression plans and have provided input into the Fire and Resource Assessment Program. Issues being addressed include timing prescribed burns to avoid fawning and nesting periods for ground-nesting birds and implementing postfire management practices that are consistent with restoring plant communities that will help to support a healthy ecosystem.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

Fire can adversely effect important habitats for fish and wildlife and impair efforts to restore fish, wildlife, and plant communities to health. Fires can reduce riparian and riverine aquatic, perennial grassland, and seasonal wetland habitats. Although fire is an important ecological process, the proliferation of invasive riparian and saltmarsh plant species has increased the potential adverse effects of fire. Some non-native plant species burn at higher temperatures and regerminate or survive at higher rates than native species, thus have a competitive advantage and can displace native species.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

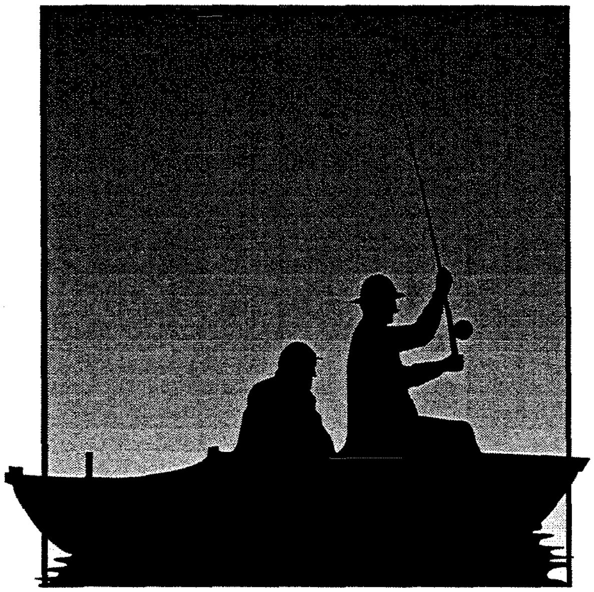
The implementation objective is to reduce the acreage and frequency of catastrophic wildfires to reduce their adverse effects on fish and wildlife and their habitats.

The following approaches would help to achieve this vision:

- Assist and coordinate restoration efforts with agencies currently responsible for managing the State's shrublands and forests by suppressing wildfires where forest management has allowed fuel levels to become excessive.

- Provide assistance to guide and implement postfire management and habitat recovery strategies to agencies charged with fire management.

- Assist local fire agencies in the Central Valley to provide additional protection to fish and wildlife habitat from catastrophic fires and reduce the risk of fire from wildlife habitats spreading to adjacent lands.



INTRODUCTION

Many Central Valley fish and wildlife species whose populations are declining are not harvested commercially or recreationally (e.g., delta smelt). This suggests that underlying problems with ecosystem processes and functions and habitat conditions throughout the Bay-Delta watershed are primary causes of the decline.

For many populations, it is highly likely that harvest restrictions, in the absence of an integrated ecosystem management program, will have little benefit in the long-term sustainability of these species.

Under current harvest levels, harvest is not a stressor limiting populations of waterfowl and upland game in the Bay-Delta. Proposed restoration of wetland and upland habitats is expected to increase resident and wintering waterfowl and upland game populations. However, the Ecosystem Restoration Program Plan (ERPP) anticipates that harvest levels would also increase in response to increased species abundance. Opportunities for increased access for public hunting may also increase as a result of some proposed actions. For example, restoration of wetland and upland habitats would involve acquiring lands through conservation easements or purchase from willing sellers and, depending on the conditions of such agreements, access for hunting may be provided.

Harvest management tools include regulations that control daily and seasonal bag limits, size limits, limits based on sex, gear restrictions, and open and closed harvest seasons based on time or location.

STRESSOR DESCRIPTION

Controlling harvest, in and of itself, is unlikely to restore fish and wildlife populations to a sustainable healthy state. The present harvest management processes are sufficient to protect species and allow population increases by restoring ecological processes that create and maintain habitats. The possible exception is related to chinook salmon and modestly reducing harvest of this species may make a significant contribution to restoring populations to desired levels. ERPP visions for chinook, salmon, steelhead, and striped bass emphasize reactivating or improving ecosystem processes that create and maintain the habitats that support fish and wildlife populations. Conservative harvest strategies during the period when habitats are being restored will accelerate the rebuilding of fish and wildlife populations.

SALMON HARVEST

In addition to applying the principles of traditional harvest management, it is necessary to consider the complexities of the interactions and dependencies between harvest, health of habitat, and the overall productivity of individual salmon populations. Harvest influences salmon productivity by reducing the number of adult fish in the spawning population, the age structure of the spawning population, and the overall fecundity (fertility) of the population because older female fish are generally larger and carry more eggs. In a much broader perspective, harvest management should strive to protect the productive capacity of individual salmon stocks by pursuing the reasonable and essential objective of protecting the genetic diversity of salmon populations upon which production ultimately depends.

Extensive ocean recreational and ocean commercial troll chinook salmon fisheries exist along the California central coast, and an inland recreational fishery exists in the Central Valley. Support of these economic and recreational uses is an important component in the overall effort to restore and maintain ecological health of the Central Valley ecosystem. Elimination of chinook salmon harvest will not restore ecological health to the system. Likewise, restoring ecological processes in the absence of conservative short-term harvest management may not provide for a sufficiently rapid rebuilding of naturally spawning chinook stocks. However, past observations indicate that Central Valley chinook populations have the ability to rapidly increase in size when there are the required riverine habitat conditions and sufficient flows for juvenile rearing and emigration.

Overall chinook salmon harvest rates must be consistent with the ERPP goal of rebuilding important salmon stocks as evaluated using the Cohort Replacement Rate method. Generally, stable chinook populations will exhibit a long-term average cohort replacement rate of 1.0. During rebuilding (which may require 10-15 years), harvest and inland conditions will be improving and rebuilding will require an average replacement rate greater than 2.0 for the less abundant runs such as the winter run and spring run.

One harvest strategy may be to implement a selective ocean fishery for hatchery stocks to reduce the harvest of naturally produced stocks. This would require the mass marking of all hatchery chinook produced at Central Valley hatcheries and perhaps in the Klamath basin, Trinity basin, and southern Oregon. Another, and perhaps more realistic option, may be to consider economic incentives for commercial and charterboat operators, as well as local businesses dependent on fishing to offset negative economic impacts associated with highly restrictive fishing.

Before 1986, harvest rates were estimated at 65-75% (PFMC 1996), which may have been too high to support a sustainable fishery. Beginning in 1986, harvest rates increased coincidently with the closure of the fishery north of Fort Bragg, California. This fishery was closed to meet harvest-sharing obligations on Klamath River stocks to Native American Tribes. This closure shifted the ocean troll fishery south to the Central Valley index area.

Many conservation biologists believe that a harvest rate of about 67% is a sustainable, conservative level for naturally spawning stocks, if quality habitat conditions exist inland. Hatchery-produced stocks can support higher rates, but sustaining high rates in the ocean mixed-stock chinook fishery also requires high harvest of naturally produced stocks.

In 1996, the Pacific Fishery Management Council (PFMC) increased the minimum size limits and decreased season length in both recreational and commercial fisheries. These actions were implemented to reduce the fishery impacts on winter-run chinook salmon by 50%. Reducing harvest is one of several major elements that will contribute in both the short and long term to restoring healthy fish populations, but it will not contribute to restoring health of important ecological processes, functions, and habitat.

According to available information, it appears that a sustainable chinook salmon fishery can be maintained if habitat conditions and ecosystem processes are restored throughout the Bay-Delta watershed, and if the ocean harvest index on naturally produced fall-run chinook salmon stocks is reduced by 10% below present levels.

Alternative actions that may support harvest reductions include a selective fishery that targets only externally marked chinook salmon and that releases unmarked fish. Selective fisheries can reduce harvest rates on unmarked fish by as much as 70-80% for gear types with low release and dropoff (shaker) mortality rates. However, the reduced harvest rates can be as little as 10-50% for gear types with high release and dropoff mortality rates. The application and benefits of a selective fishery for the central California coast ocean mixed-stock fishery are unknown. The potential effectiveness of a selective fishery in increasing spawning escapements of unmarked fish depends on the following factors:

- the proportion of a naturally spawning stock that would be harvested by the fishery in the absence of selective regulations,
- the impact of nonselective fisheries that harvest unmarked fish that are released in selective fisheries,
- the degree to which reduction in total abundance caused by mortality resulting from application of tags or other distinguishing marks increases harvest rates in nonselective fisheries that operate under catch quotas or bag limits, and
- the magnitude of harvest rate reductions resulting from the selective fishery.

In addition to considering the potential implementation of a mass marking and selective fishery along the California coast, ERPP is also considering the feasibility of providing economic incentives for commercial and charterboat operators to offset negative economic effects of short-term reduced harvest.

Attainment of the ERPP vision for chinook salmon harvest will rely on actions by the California Fish and Game Commission and PFMC. PFMC and seven other regional councils were created by the Magnuson Fishery Conservation and Management Act in 1976. Their primary role is to develop, monitor, and revise management plans for fisheries conducted within 3 to 200 miles of the United States coast. PFMC develops plans for ocean fisheries off California, Oregon, and Washington.

The ocean salmon fisheries off Washington, Oregon, and California have been managed by the PFMC since 1977 by using Fishery Management Plans (FMP). Since the beginning of the 1985 season, the ocean salmon fishery has been managed by a framework FMP that allows flexibility to adjust annual regulations in response to varying stock abundance.

The framework FMP contains fixed management objectives and goals that guide the PFMC's choice of flexible annual management measures. Within specified limits, PFMC may vary season length, management boundaries, bag limits, gear restrictions, and quotas annually to achieve the fixed objectives of the FMP. Some of the major provisions of the FMP are a description of the salmon stocks comprising the management unit, management objectives, and escapement goals and procedures for determining and allocating ocean harvests and in-season management procedures.

It is important to distinguish ERPP's vision for chinook salmon and the roles and responsibility of other management authorities, particularly PFMC. Although ERPP provides a long-term comprehensive plan to restore the ecosystem health of the Bay-Delta system, the harvest management objectives of PFMC are to:

- establish ocean harvest rates for commercial and recreational fisheries that are consistent with requirements for optimum spawning escapements, treaty obligations, and continuance of established recreational and commercial fisheries within the constraints of meeting conservation and allocation objectives.

- minimize fishery mortalities for those fish not landed from all ocean salmon fisheries as consistent with optimum yield;

- manage and regulate fisheries so the optimum yield encompasses the quantity and value of food produced and the recreational, social, and economic values of the fisheries;

- develop fair and creative approaches to managing fishing effort and evaluate and apply management systems as appropriate to achieve these management objectives;

- achieve long-term coordination with the member states of PFMC, the treaty Native American tribes, and management entities that are responsible for salmon habitat or production in the development of a coastwide salmon management plan;

- manage in a manner consistent with any United States-Canada salmon treaty; and

- support the enhancement of salmon stock abundance in fishing-effort management programs to facilitate a return to economically viable and socially acceptable commercial, recreational, and tribal seasons.

In addition to its management objectives, PFMC has established a set of conservation goals, many of which are consistent with ERPP. In recognizing that maintenance of a healthy resource is necessary to achieve continuing benefits to the nation, PFMC will adhere to the following conservation goals:

- Assume a more aggressive role in protecting and enhancing anadromous and marine fish habitat. PFMC will play a leadership and coordination role to support the agencies having management responsibilities and authorities.

- Manage for viable salmon stocks and maintain genetic diversity. PFMC recognizes that in areas of importance to particular stocks, habitat degradation and water development may leave no alternative but to manage for hatchery production or a combination of hatchery and natural production.

- Strengthen its efforts to work with other jurisdictions, both domestic and international, to manage stocks of fish over their entire range.

- Strongly support development of concepts and practices for managing mixed-stock and multispecies complexes and rebuild those complexes to best meet the economic and allocation objectives of PFMC.

- Support additional data collection and analyses that will improve the basis for management measures.

- Develop management measures that constrain incidental catches of fish and other animals within acceptable limits while target species are being harvested.

STEELHEAD TROUT HARVEST

The harvest of both naturally and hatchery-produced juvenile steelhead takes place throughout the Sacramento basin. Juvenile harvest is not desirable because it reduces the future adult population size, the opportunity for anglers to harvest adult steelhead, and the overall productivity and fecundity of spawning populations.

More restrictive angling regulation may be necessary to protect steelhead from overharvest and still allow anglers the opportunity for continued sport fishing. The following elements might be considered as additional protective measures for steelhead: catch-and-release fishing only, catch-and-release fishing where hooked fish are not removed from the water to decrease handling mortality, size limits to protect either juvenile fish or larger adult spawners, and barbless hooks to reduce latent mortality.

ERPP supports special recognition of the steelhead fishery of the Yuba River as an important wild steelhead fishery. As part of this recognition, regulations should be enacted to protect this valuable stock while allowing controlled angling opportunities that have a minimal adverse effect on the spawning population. ERPP also supports prohibiting the harvest of juvenile steelhead and rainbow trout in the Yuba River while providing anglers with opportunities for catch-and-release fishing for wild steelhead in other streams.

STRIPED BASS HARVEST

Adult striped bass support the most important sport fishery in the Sacramento-San Joaquin estuary, and the condition of this fishery is publicly recognized as a barometer of the status of the estuary and its biological resources. Statewide, more than 400,000 anglers fish for striped bass and most of this effort is directed at the Sacramento-San Joaquin estuary population. Unfortunately, because of the depressed state of the population, the present annual harvest of striped bass from the Sacramento-San Joaquin system is only about 80,000 fish. Recent annual harvest rates have ranged from 9-14%. In the early 1970s, when striped bass were more abundant and more anglers fished, harvest rates of 16-24% led to the harvest of more than 300,000 legal-sized fish annually. Annual harvest may have reached 750,000 fish from the high populations of the early 1960s.

ERPP supports the legal harvest of striped bass because it has not caused the decline in abundance that has occurred since the 1960s and 1970s. At the same time, efforts to curtail illegal harvest (taking undersized fish and catching over limits) should be vigorously continued. The goal of increased legal harvest should be attained by maintaining present angling regulations while increasing the abundance of adult fish. Although angler participation most likely will expand as fishing success increases, it is anticipated that present angling regulations will keep harvest rates at sustainable levels (<20%).

WHITE STURGEON HARVEST

White sturgeon provides for an important recreational fishery in the Bay-Delta. Although, commercial fishing for sturgeon is prohibited in California, historical accounts indicate that commercial fisheries greatly reduced west coast sturgeon populations, including the Sacramento-San Joaquin population, in the late 1800s. As a result, all sturgeon fishing was prohibited in 1917; the fishery was reopened in 1954 to sport angling only. With the exception of 1956 to 1963, when the minimum size limit was raised to 50-inch total length (TL), the sport fishery had the same regulations from its inception until 1989: a year-round season, 40-inch TL minimum size limit and a one-fish-per-day creel limit.

Although fluctuations in legal-sized white sturgeon abundance have been primarily dependent on variable recruitment, historical depletion by the commercial fishery indicates that the population is readily subject to overharvest. Consequently, a 40% increase in the average annual harvest rate from 7% in the 1960s and 1970s to 10% in the 1980s was cause for concern and was the impetus for angling regulation changes in the early 1990s. Starting in 1990, a maximum size limit of 72 inches was instituted and the minimum size limit was increased in 2-inch annual increments until it reached 46 inches in 1992. This slot limit is designed to protect older, more productive fish and younger fish that will be recruited into the spawning population and also to reduce overall harvest.

These angling regulations have achieved their purpose; estimated harvest rates have been <3% in recent years. Therefore, ERPP envisions supporting the present harvest strategy that protects the white sturgeon from overexploitation while providing anglers with a sustainable trophy fishery.

HARVEST OF WILDLIFE

Under current harvest levels, harvest is not a stressor limiting populations of waterfowl and upland game in the Bay-Delta. Because proposed restoration of wetland and upland habitats is expected to increase resident and wintering waterfowl and upland game populations, however, ERPP anticipates that harvest levels would also increase in response to increased species abundance. Opportunities for increased access for public hunting may also increase as a result of some proposed actions. For example, restoration of wetland and upland habitats would involve acquiring lands through conservation easements or purchase from willing sellers and, depending on the conditions of such agreements, access for hunting may be provided.

ILLEGAL HARVEST OF FISH AND WILDLIFE

The illegal harvest of fish and wildlife is known to be a problem throughout the Bay-Delta watershed. It may range from the illegal take of adult spring-run chinook salmon from their oversummering habitats in the upper sections of stream tributary to the Sacramento River, to the illegal take of undersized striped bass in the Delta. Illegal harvest can also be in the nature of a more commercial activity such as using gillnets to catch adult salmon, sturgeon, and striped bass in the Delta for sale and profit.

By its very nature, illegal harvest is difficult to control or eliminate. ERPP envisions that the California Fish and Game Code will be enforced by increasing law enforcement officer staff and that reductions in the illegal take of fish and wildlife could make important contributions in rebuilding depleted stocks. ERPP also envisions that directed enforcement is only one avenue to reduce illegal harvest and that a strong public education program is critical to the success of the enforcement effort.

VISION

The vision for fish and wildlife harvest is to support strategies that maintain a sustainable commercial and recreational chinook salmon fishery in a manner consistent with the recovery; of individual stocks; steelhead trout harvest strategies that fully protect naturally spawning stocks while redirecting harvest to hatchery-produced stocks; the continued legal harvest of striped bass and reduction of illegal harvest; and the present white sturgeon harvest strategy, which protects the species from overexploitation while providing a sustainable trophy fishery.

The vision for salmon harvest is to implement strategies that support and maintain sustainable commercial and recreational fisheries. Achieving this vision would be consistent with ecosystem restoration and recovery of endangered species and species of special concern. ERPP proposes both short-term and long-term strategies for harvesting chinook salmon.

The short-term strategy is to support the rebuilding of chinook salmon stocks to desired levels by reducing harvest of naturally produced fish.

The long-term strategy is to increase chinook salmon populations by restoring important ecosystem processes and reducing or eliminating stressors that cause direct and indirect mortality.

In the long-term vision, ERPP anticipates sustainable ocean commercial harvest landings of 750,000 to 1,500,000 chinook salmon and recreational landings of 500,000 to 750,000 per season.

The vision for steelhead trout is to support harvest strategies that fully protect naturally spawning stocks while redirecting harvest to hatchery-produced stocks. This will require a marking program similar to the mass marking program proposed for chinook salmon, except the number of fish to mark would be lower. In this vision, adult steelhead harvest would be directed to steelhead produced at Coleman National Fish Hatchery on Battle Creek, Feather River Hatchery on the Feather River, Nimbus Hatchery on the American River, and Mokelumne River Fish Installation on the Mokelumne River. Harvest of these stocks would also occur on the mainstem of the Sacramento River.

The vision for striped bass harvest is to support artificial production needed to sustain annual recreational harvest of about 20% of the adult population. The vision for striped bass is closely integrated with visions for other ecosystem elements that will contribute to higher survival of resident, estuarine, and anadromous fish. This higher survival will be achieved through extensive habitat restoration, reduction or elimination of stressors, and the reactivation of ecological processes that create and maintain habitats.

The vision for white sturgeon is to support the annual recreational harvest of less than 3% of the adult population which will protect population while providing opportunity for a trophy fishery. The vision for white sturgeon is also closely linked to the visions for Central Valley streamflows, habitat improvement, and the reduction of elimination of stressors that cause direct and indirect mortality to young fish.

The vision for illegal harvest is that increased enforcement efforts and public education will reduce the adverse effects to a level consistent with restoring fish and wildlife populations.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Three major programs to restore chinook salmon and steelhead populations exist within the Central Valley.

- The Secretary of the Interior is required by the Central Valley Project Improvement Act to double the natural production of Central Valley anadromous fish stocks by 2002 (USFWS 1997).
- The National Marine Fisheries Service is required under the federal Endangered Species Act to develop and implement a recovery plan for the endangered winter-run chinook salmon and to restore the stock to levels that will allow its removal from the list of endangered species (NMFS 1997).
- The California Department of Fish and Game is required under State legislation (The Salmon, Steelhead Trout and Anadromous Fisheries Program Act of 1988) to double the numbers of salmon and steelhead trout that were present in the Central Valley in 1988 (Reynolds et al. 1993, McEwan and Jackson 1996).

In addition the Fish and Game Commission adopts regulations for the harvest of fish and wildlife, sets seasons, bag limits, closed areas, gear restrictions and a variety of other tools to control the harvest of fish and wildlife species. The Pacific Fishery Management Council annually sets harvest regulations for the areas along the Pacific Coast south of British Columbia.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

One of the most important components of the ERPP is restoring health to fish populations in the ERPP Study Area. Some of these species, such as winter-run chinook salmon, are State or federally listed endangered species. Others species, such as splittail and steelhead, are species of concern, and spring-run chinook salmon is designated a monitored species by the Fish and Game Commission. Overall health of fish and wildlife species is closely linked to the health of ecological processes that create and maintain habitats needed by these species. Improving the ecological functions will also improve habitat. Concurrently, a reduction or elimination of stressors will contribute to improved functions, habitats, and species.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective is to regulate harvest to the extent necessary to avoid impairing the reproductive capacity of the populations in relation to available habitats.

The general target is to control harvest in a manner which contributes to attainment of fish population goals established by State and federal legislation and in a manner consistent with restoration of ecosystem health.

Actions which will contribute to this vision include:

- Adaptive management and focused research programs to mark hatchery produced chinook salmon to provide harvest and return data to better manage harvest.
- Reduce ocean harvest rates to 40-50%.
- Mark all hatchery produced steelhead and evaluate the benefits of implementing a selective fishery which targets only marked fish.
- Provide special recognition to the Yuba River as an important wild steelhead fishery.
- Augment the striped bass population and recreational fishery by artificial production.
- Maintain the existing regulations for the white sturgeon trophy fishery.
- Increase enforcement efforts directed at illegal harvest.
- Develop a public education program designed to reduce the illegal harvest of fish and wildlife in the ERPP Study Area.

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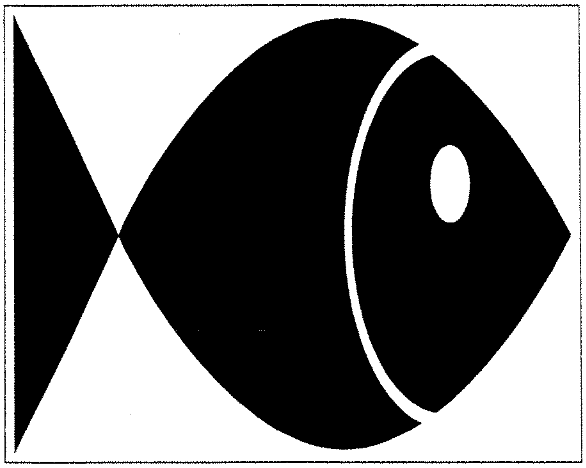

INTRODUCTION

The Ecosystem Restoration Program Plan (ERPP) recognizes that artificial propagation of fish has been an important tool used by salmon managers in the Central Valley for over a century. The intended goal of hatchery operation has consistently been for mitigation—typically for the non-retrievable loss of valuable migration, holding, spawning, rearing, and emigration habitats that were cut off by large dams throughout the Central Valley.

Hatchery production makes a significant contribution to commercial and sport fisheries as well as their role in providing mitigation for loss of habitats from the construction of large dams. ERPP envisions the integration of an effective management program of existing or new hatchery facilities with harvest and population management strategies that will work together to restore and sustain the health of fish species dependent on the Bay-Delta. In addition, the artificial propagation of striped bass would be an interim measure to provide for the maintenance of a healthy population and valuable sustainable sport fishery until such time that striped bass are capable of sustaining naturally spawning population levels present in the late 1960s and early 1970s (approximately three million adults).

STRESSOR DESCRIPTION

Five hatcheries currently produce chinook salmon in the Central Valley. The three largest hatcheries (Coleman, Feather River, and Nimbus) are in the Sacramento River Basin (Table 5), and the Mokelumne and Merced River hatcheries are in the San Joaquin Basin. Most of these salmon hatcheries were constructed between 1940 and 1970 as mitigation for specific dams and water projects, and are funded by mitigation agreements with State, federal, and public agencies and monies collected from commercial salmon fishers.

Before 1967, Nimbus and Coleman were the only hatcheries with substantial production rates, but between 1967 and 1991, total Central Valley salmon production nearly doubled. Central Valley hatcheries now produce an annual average of nearly 33 million juvenile fall-run chinook, more than one million juvenile spring-run chinook, about 0.6 million juvenile late-fall-run chinook, and more than 2.5 million juvenile steelhead.

Releasing large numbers of hatchery fish, however, can pose a threat to wild chinook stocks. Potential consequences include genetic impacts on wild fish (e.g., outbreeding and inbreeding), competition for food and other resources between wild and hatchery fish, predation of hatchery fish on wild fish, and increased fishing pressure on wild stocks as a result of hatchery production (Waples 1991). Potential impacts to native gene pools must be evaluated in light of evidence for genetic changes in hatchery stocks (e.g., random genetic drift, selection, stock transfers, and straying), which can determine the nature and

CENTRAL VALLEY SALMON AND STEELHEAD PRODUCTION HATCHERIES AND THE AVERAGE ANNUAL PRODUCTION OF CHINOOK SALMON AND STEELHEAD

		Average Annual Production				
		Chinook Salmon Stock				
Facility[1] and Period of Record	Location	Fall	Spring	Late-Fall	Winter	Steelhead
Feather River Hatchery (1968-1993)	Feather River	7,434,000	1,219,000[2]	N.P.[3]	N.P.	751,000
Nimbus Hatchery (1965-1993)	American River	8,810,000	N.P.	N.P.	N.P.	767,000
Mokelumne River Hatchery (1965-1993)	Mokelumne River	946,000	N.P.	N.P.	N.P.	161,000
Merced River Hatchery (1970-1993)	Merced River	579,000	N.P.	N.P.	N.P.	N.P.
Coleman National Fish Hatchery (1940-1993)	Battle Creek[4]	14,941,000	N.P.	639,000	26,000	814,000
Sum of average statewide production		32,710,000	1,219,000	639,000	26,000	2,493,000

1 All facilities are operated by the California Department of Fish and Game, except that Coleman National Fish Hatchery is operated by the U.S. Fish and Wildlife Service.

2 Spring-run chinook propagated at Feather River Hatchery are believed to have interbred with fall-run chinook.

3 N.P. = not produced.

4 Battle Creek is a tributary of the Sacramento River.

magnitude of interactions between hatchery and wild fish.

There is little evidence with which to evaluate past and current genetic impacts of Central Valley salmonid hatchery programs on the naturally spawning chinook salmon and steelhead populations. Bartley and Gall (1990), using protein electrophoresis, found that populations of chinook salmon from Central Valley hatcheries were genetically similar to wild populations and speculated that the releasing hatchery fish in the Delta may have resulted in abnormally high straying and gene flow to native stocks. However, the great genetic similarity among all Central Valley chinook populations makes it difficult to detect genetic impacts from hatchery releases. An alternative hypothesis that cannot be disproved with present data is that Central Valley hatchery stocks have diverged little from their wild ancestors, in which case the near-term genetic impacts of hatchery programs might be minimal. DNA studies may shed light on this problem (Nielsen et al. 1994).

The general literature on the genetic impacts of artificial propagation programs on Pacific salmonids suggests that Central Valley hatcheries could have serious, direct and indirect, negative effects on the naturally spawning chinook salmon and steelhead. Straying hatchery fish, for example, is a major cause of hybridization between hatchery and wild fish (Waples 1991). Although straying, primarily among neighboring streams, is a natural phenomenon, hatchery fish have been documented to stray farther and at a higher rate than wild fish. In the Central Valley, two hatchery practices in particular might contribute to elevated straying levels: trucking smolts and yearlings to distant sites for release and transferring eggs and young fish between hatcheries. These are both practiced at Feather River and Nimbus hatcheries.

Increased production and survival of hatchery chinook salmon have resulted in increasing contributions of hatchery fish to adult spawning escapements since 1967. When hatcheries are successful at producing adult fish, the potential harvest rate may become very high. Fewer adults are needed to maintain a hatchery run because of high survival from eggs to smolts under hatchery conditions. This plants high percentages of returning hatchery fish to be harvested while still sustaining the hatchery run. As harvest rates are raised to match the potential productivity of hatchery stocks, wild stocks may become overfished.

Current harvest rates of Central Valley chinook salmon stocks are high enough to adversely affect the natural production in some rivers and adversely affect naturally produced chinook salmon stocks. Accurate quantification of the Central Valley hatchery contribution to the ocean catch of chinook salmon has not been developed because of the lack of a consistent hatchery marking program in the Central Valley. Nonetheless, Dettman and Kelley (1987) estimated that from 1978 through 1984, an average of 11% of ocean catches off California comprised Feather River hatchery fish, and an average of 13% comprised American River hatchery fish. The percentage of annual contributions of hatchery fish to escapement in recent years has been estimated as follows:

- for the Feather River, 26% average for 1975-1987 (Cramer 1990) and 78% average for 1975-1984 (Dettman and Kelley 1987);
- for the American River, 29% average for 1975-1987 (Cramer 1990) and 86.6% average for 1975-1984 (Dettman and Kelley 1987);
- for the middle Sacramento River, 40% average for 1975-1987 (Cramer 1990); and
- for the upper Sacramento River, 41% average for 1975-1988 (Cramer 1990).

VISION

The existing level of reliance on artificially produced fish in the Central Valley is clear evidence that there are great deficiencies in the existing ecosystem processes that create and maintain habitat for anadromous fish. Extensive restoration activities will be required to shift the balance back to naturally produced fish populations.

The vision for the artificial propagation of fish is closely linked to ERPP visions for harvest, chinook salmon, steelhead trout, and striped bass. Cumulatively, these visions present a robust integration of production, harvest, and restoration targets and actions that will contribute substantially to restoring and maintaining a healthy ecosystem and healthy populations of valuable sport and commercial fisheries.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Three major programs to restore chinook salmon and steelhead populations exist within the Central Valley. The Secretary of the Interior is required by the Central Valley Project Improvement Act (Public Law 102-575) to double the natural production of Central Valley anadromous fish stocks by 2002 (USFWS 1995). The National Marine Fisheries Service is required under the federal Endangered Species Act to develop and implement a recovery plan for the endangered winter-run chinook salmon and to restore the stock to levels that will allow its removal from the list of endangered species. NMFS released this document in August 1997 (NMFS 1997). In August 1996, NMFS published a proposed rule to list tem Evolutionarily Significant Units west coast steelhead at threatened or endangered under the ESA. Included in this proposed rule was a proposal to list the Central Valley stock of steelhead as endangered. NMFS subsequently deferred list the Central Valley steelhead stock for six month due to scientific disagreement about the status of the stock.

The California Department of Fish and Game is required under State legislation (The Salmon, Steelhead Trout and Anadromous Fisheries Program Act of 1988) to double the numbers of salmon and steelhead trout that were present in the Central Valley in 1988 (Reynolds et al. 1993, McEwan and Jackson 1996).

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

One of the most important components of the ERPP is restoring health to fish populations in the ERPP Study Area. Some of these species, such as delta smelt and winter-run chinook salmon, are State or federally listed endangered species while others, such as splittail and steelhead, are species of concern. Artificial production programs in the ERPP Study Area need to be consistent with the principles of maintaining genetic diversity of natural stocks. These programs also need to be adaptive and implement operations to limit hatchery and wild fish interactions to reduce competition, predation, and the potential spread of diseases.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

The implementation objective for artificial propagation of fish is to reduce the potentially adverse effects of stocking artificially produced fish throughout Central Valley rivers and streams in order to increase the survival of naturally produced fish, contribute to long-term restoration goals, and maintain the genetic diversity of naturally producing populations of chinook salmon and steelhead populations.

The general targets for the artificial production of fish are:

- propagation programs would be managed consistent with rehabilitation of chinook salmon and steelhead stocks and the conservation of ecological and genetic values;
- propagation programs would adopt a goal of maintaining the genetic diversity that exists between and within hatchery and naturally spawning populations;
- all artificially propagated fish should receive identifiable marks; and
- decision making about the uses of hatcheries and artificially propagated fish should occur within the context of a fully implemented adaptive management program that focuses on restoration of ecological processes and habitats, not simply the number and quality of fish successfully propagated.

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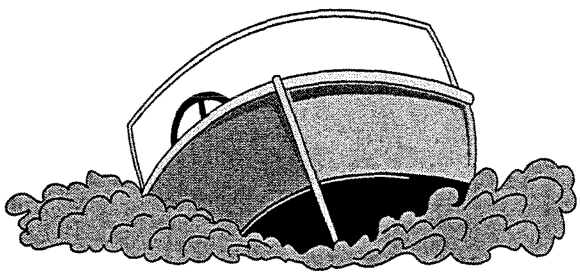


INTRODUCTION

Disturbance resulting from human activities can adversely affect habitat for a substantial variety of fish, wildlife, and plant communities including many special-status species and plant communities listed as endangered or threatened on the California and federal Endangered Species Acts (ESAs) lists. The types of disturbance include those associated with recreational boating, angling and picnicking, airplane and vehicle traffic, and the secondary effects of residential development adjacent to wildlife habitat

The Ecosystem Restoration Program Plan (ERPP) proposes to reduce disturbance where species, such as the Swainson's hawk, nest. Establishing habitat buffers around sensitive habitat or wildlife use areas (e.g., Swainson's hawk nest sites) screens wildlife from disturbance associated with motor vehicle traffic and reduces recreation-related disturbance while still allowing for careful wildlife observation activities.

Carefully designing recreational access points can also reduce the level of disturbance on wildlife (e.g., locating access points to avoid impacts to levees and to keep trespassing and vandalism of private lands to a minimum).

The vision includes providing opportunities for recreational boating in a manner that reduces the impacts of those activities on fish and wildlife. This could be achieved by improving recreational boating opportunities in selected areas of the Delta for both motorized and nonmotorized craft while reducing or eliminating boating by closing sensitive biological areas during specific seasons.

STRESSOR DESCRIPTION

Recreational boating is a popular activity in the ERPP study area, particularly in the Sacramento-San Joaquin Delta and Suisun Marsh/North San Francisco Bay Ecological Zones. Boating activities include the use of small, human-powered craft, such as canoes and kayaks, and individual motorized craft such as jet skis, sail boats, boats ranging from small fishing skiffs to ski boats, and larger pleasure craft. Wind surfing is also expanding in popularity. Excessive, unrestricted boating activities can result in increased erosion of adjacent channel banks, increased turbidity, and conflicts with other boat operators using the same channels.

Angling and picnicking are also popular activities. Unrestricted human entry for these and other activities has contributed to levee degradation in the Delta, littering, and wildfires and can increase the likelihood of trespass and vandalism on private lands.

Vehicle traffic close to wildlife habitat reduces the value of that habitat to wildlife, particularly to species such as the greater sandhill crane. Aircraft traffic (both fixed-wing and helicopter) associated with the application of agricultural chemicals can also contribute to the disturbance of wildlife in the Delta.

Disturbance associated with the pets of people who live near wildlife habitat can result in harassment of wildlife, particularly ground-nesting birds.

VISION

The vision for disturbance is to reduce the adverse effects of boating and other recreational activities, temporary habitat disturbances, and other human activities on wildlife and their habitats in the Bay-Delta.

ERPP's general approach to achieving the vision for this stressor will be to ensure that the location of restored habitat takes into account adjacent land uses, that adequate buffer areas to protect against disturbance are used, and that recreational activities are managed to avoid or minimize conflicts with fish and wildlife habitat. Recreators should be provided with adequate facilities in areas that are not sensitive to fish and wildlife and where trespass onto adjacent private lands can be avoided.

INTEGRATION WITH OTHER RESTORATION PROGRAMS

Agencies charged with regulating activities within their respective jurisdictions include the U.S. Coast Guard, California Department of Boating and Waterways, California Department of Parks and Recreation, local park districts such as the East Bay Municipal Parks District, local sheriffs in the affected counties, California Department of Fish and Game, California Department of Water Resources, and U.S. Fish and Wildlife Service.

LINKAGE WITH OTHER ECOSYSTEM ELEMENTS

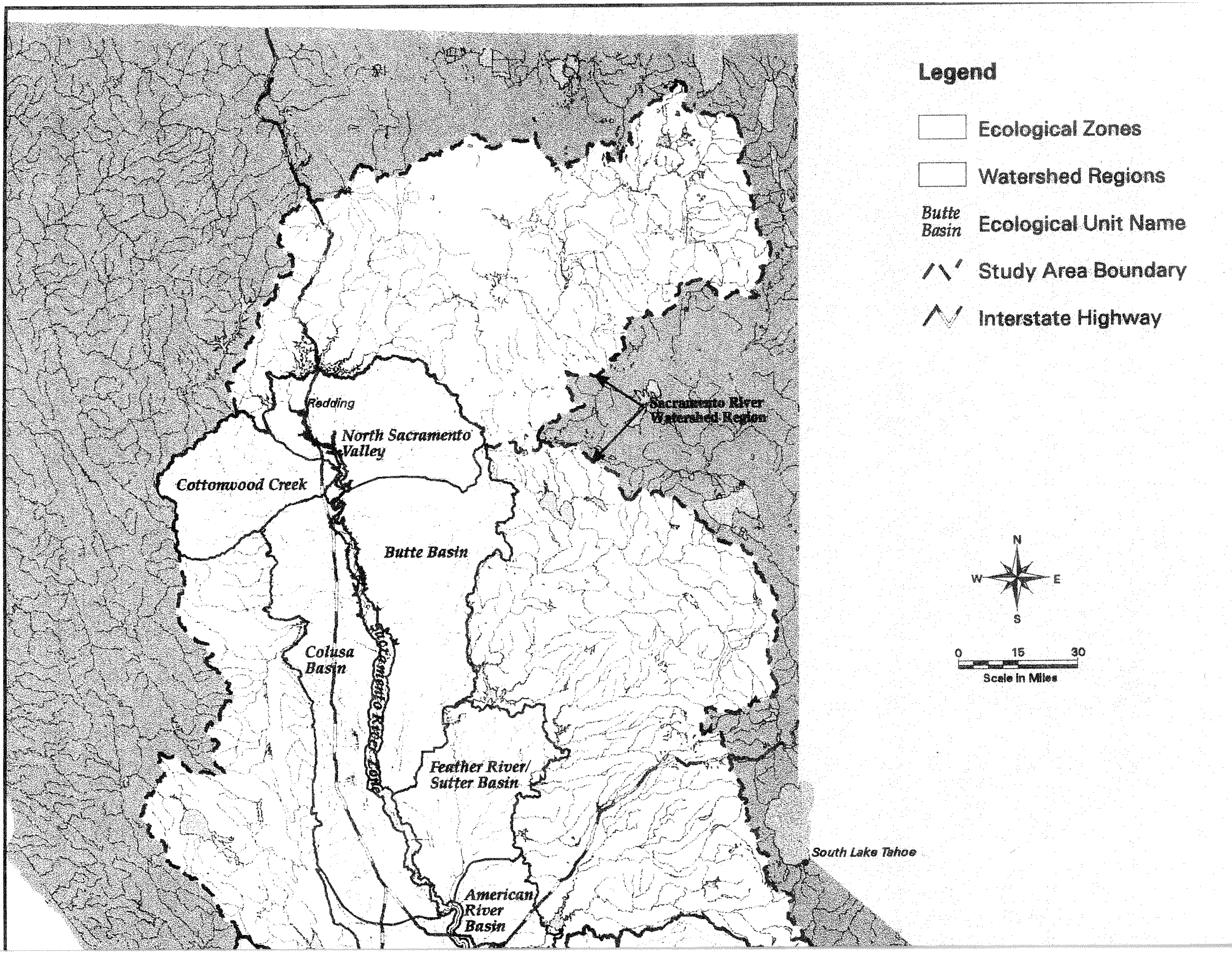
Human caused disturbance adversely affects habitats and species. Boat wake shoreline erosion can impair ERPP efforts to protect and restore shoreline vegetation and shallow water emergent vegetation, particularly in the Delta and along the mainstem Sacramento and San Joaquin Rivers. Human presence can also disturb populations of special status fish, wildlife, and plant species.

IMPLEMENTATION OBJECTIVE, TARGETS, AND PROGRAMMATIC ACTIONS

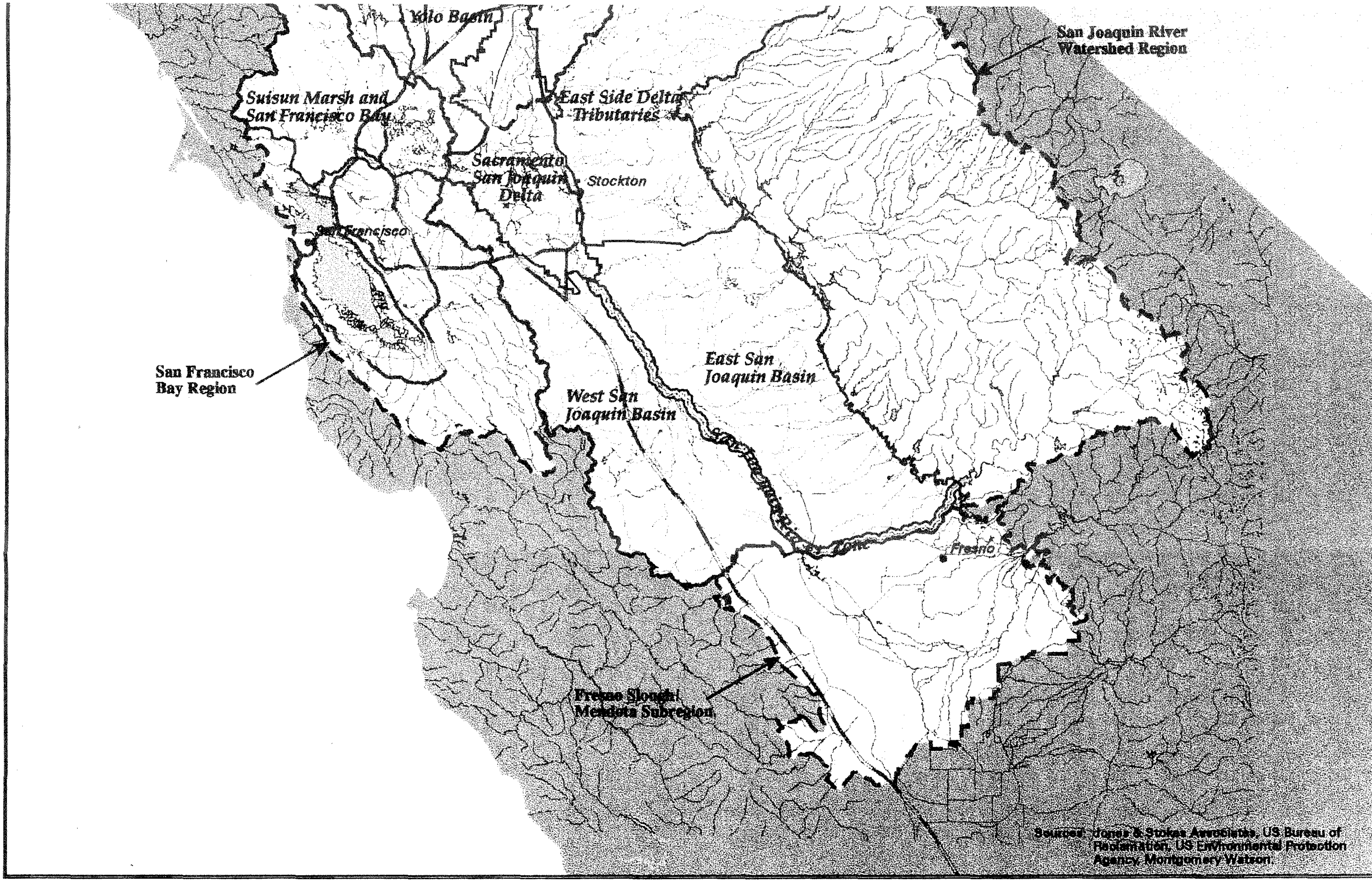
The implementation objective for disturbance is to reduce human activities that adversely affect wildlife behavior or cause habitat destruction. Reducing these activities would increase reproductive success and contribute to restoration of important species.

The following approaches would help achieve this vision:

- Cooperate with agencies responsible for managing the State's recreational activities to ensure properly sized and sited facilities will be provided and maintained.
- Cooperate with the Department of Boating and Waterways, U.S. Coast Guard, and local mariner organizations to identify the need and feasibility of, and implement where feasible, seasonal boating closures in sensitive wildlife use areas while maintaining alternative boating opportunities.



Legend
Ecological Zones
Watershed Regions
Butte Basin
Ecological Unit Name
Study Area Boundary
Interstate Highway
N
W
E
S
0
15
30
Scale in Miles
Redding
North Sacramento Valley
Cottonwood Creek
Butte Basin
Colusa Basin
Sacramento River Zone
Feather River/ Sutter Basin
American River Basin
Sacramento River Watershed Region
South Lake Tahoe



CALFED
BAY-DELTA
PROGRAM

Ecosystem Restoration Program Plan

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Figure 1
ERPP Study Area and Ecological Zones

April 8, 1997